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The difficulty lies, not in the new ideas, but in escaping the old ones.

John M. Keynes

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A forum for the exchange of views on science and science policy.

Guest Editor: David Lillis
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Instructions to Authors

NZ Science Review provides a forum for the discussion of Science policy. It covers science and technology in their broadest sense and their impacts on society and the environment both favourable and adverse. It also covers science education, science planning and freedom of information. It is aimed at all scientists and decision makers, and the interested public. Readability and absence of jargon are essential.

Manuscripts on the above topics are welcome, two copies of which should be sent to: The Editor
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As well as full papers, short contributions, reports on new developments and conferences, and reviews of books, all in the general areas of interest of the journal, are invited. The journal also accepts reviews of a general nature and research reports.

Full manuscripts (with author's name removed) will be evaluated and authors will be sent copies of the reviewer's comments and a decision on publication. Manuscripts should not normally have appeared in print elsewhere but already published results discussed in the different, special context of the journal will be considered. They should preferably not exceed 2500 words.

To facilitate anonymous review, author's names on manuscripts and any acknowledgement of assistance should be on a detachable cover page. Manuscripts should be accompanied by biographies of not more than 100 words on each author's personal history and current interests. Authors are also expected to supply a suitable photograph of themselves.

Manuscripts should be typed double-spaced with wide margins on one side of the page. Articles may be submitted in common wordprocessor formats on floppy disks. Tables and figures should be on separate pages with a note in the text to indicate their approximate position, eg "Table X about here".

All tables, figures and plates should be numbered separately: Tables 1, 2, 3, 4, etc, and Figures 1,2, 3, 4, etc. Footnotes should be eliminated as far as possible. Black and white photographs may be submitted for consideration for publications.

References should preferably be cited by the Harvard system as described in the NZ Government Printing Office *Style Book*, 3rd ed. (1982), p. 21. This system entails citing each author's surname and the year of publication in the text and an alphabetical listing of all author's cited at the end. Occasionally an alternative system may be justified and this is acceptable provided that it is used accurately and consistently.

Tribute to Crop & Food staff who died in the air accident of Friday, 6 June 2003

The New Zealand science community was badly shaken by the tragic air accident near Christchurch airport in which seven senior management staff from Crop & Food Research lost their lives, along with the pilot of the aircraft.

Words cannot express the deep sense of loss that is felt, not only by the families, but also by scientific colleagues and friends who had close acquaintances with the victims. Each of them was involved in a close network of professional and personal relationships, and those linkages crossed national and international boundaries. Science leadership, management and communication were their professional skills, and the knowledge and expertise that they held and applied, both individually and collectively as members of the senior management team, is irreplaceable. Their legacy is a vibrant and robust institution with a very diverse range of research programmes. The challenge for the coming months will be for the institutional leadership of Crop & Food, with the help of those that survived the accident, to build on the strong foundations laid down by those who lost their lives.

Council of the New Zealand Association of Scientists and its membership throughout New Zealand offer their sincere condolences to family, friends and scientific colleagues of Howard Bezar, Katherine Carman, Alistair Clough, Richard Finch, Desma Hogg, Andrew Rosanowski, and Margaret Viles.

Editorial

Science Objectives, Strategies and Policy

For this Special Science Policy Issue of *NZ Science Review* we have solicited a wide range of contributions from key players concerned with the aims, strategies, tactics and policies of the New Zealand science system. The ideas expressed in these articles are of great importance, not only for what they say, but often for what they do not say.

In these documents we might expect to see a clear enunciation of Government's aims for the science sector (or Target Outcomes, to use the current parlance). We might also expect to see a clear description of context (e.g. whether investment in science and technology will be a static, increased or even a falling, proportion of GDP), some discussion of the strategies and tactics that might be employed in arriving at the stated aims, and critiques of the successes and failings of the system. We certainly got critiques, but in general, these were focused on the economy, and rather fewer contributions were devoted to other areas of public good science.

Clear statements from the Ministry of Research, Science, and Technology (MoRST) set out the enhanced role that Government wishes for science and technology as a contributor to growth of the nation's economy. Unfortunately, MoRST's paper does not set out clear aims for other science sectors such as the environment and human health capital. In fact, Nick Allison, of the Foundation for Research, Science and Technology (FRST), refers to Target Outcomes such as 'Healthy, Diverse and Resilient Ecosystems' as platitudes that hardly provide benchmarks for forming priorities. Likewise, Anthony Scott, of the Association of Crown Institutes, notes a lack of clarity surrounding the purpose and expectations of the science system. Janet Grieve, of the Council of the New Zealand Association of Scientists, notes a lack of coherence between what Government says about its expectations of the environmental science sector and the resources actually provided to this sector.

Although reasonably transparent strategies and tactics are articulated for sectors that produce economic outputs, little is said about sectors that don't. With hindsight, it would be easy to interpret these omissions as a deliberate strategy to dis-invest from the non-economic sectors. For example, the changing of the definition of environmental science to include energy research and research aimed at mitigating environmental damage caused by particular sectors of the economy, appears to be a deliberate ploy to obscure what has actually happened to funding to that sector. Because of this change, core environmental research is grossly under-resourced, although appearing superficially to be funded as well as ever. Because these strategies are not transparent, there has been little evaluation of their implications for other areas of Government's investment interest.

Some of the present chaos has led two contributors (Sean Devine and Peter Winsley) to want to throw the whole system up in the air again. The Association believes that there is no need for radical change. First, clear purposes for the New Zealand Science System need to be articulated, and clear processes and policies formulated to ensure that these purposes are implemented. The Association has contended for a number of years now that there is a need for an open priority-setting process to ensure that all stakeholders have an opportunity to make input. More than anything, New Zealand's science priority-setting process has been bureaucratised and politicised in recent years, largely excluding working scientists. Good management practice demands an inclusive process that involves all stakeholders in formulating direction for the science innovation system. In this way, scientists and technologists will feel part of the team rather than pawns in a distant, careless bureaucracy. Monitoring and analysis of the evolving science system are essential if we are to optimise outcomes in a rapidly changing world.

Council of the New Zealand Association of Scientists

Foreword

This edition was conceived by the Council of the New Zealand Association of Scientists last year with the intention of collecting into a single issue some of New Zealand's best strategic thinking about research, science and technology. We thank all the contributors for providing copy for this volume.

It is absolutely critical to get our national objectives, policies and plans right if our national science strategy is to be implemented successfully. The long term impact of a poor science strategy on a country's future can be nothing short of disastrous, but getting it right can deliver (literally) benefits to all. Given the limited research, science and technology resources Government is willing to make available in New Zealand, it is essential that we do get it right.

In developing science and technology strategy and policy it must be remembered that the real value of research lies in the long term. Almost always its value is underestimated, often unknown at the time, and then frequently not acknowledged when the benefits flow. David Penny put the situation nicely in perspective in his 1991 Presidential Address, "...Politicians and their fads come and go; science, knowledge and technology is what is ultimately important".

Peter Winsley, drawing on his own perspectives as former science policy adviser at the Foundation for Research, Science and Technology, has outlined his observations of the current science system. He notes an overall lack of strategic direction and a focus on input-orientation or science push, and he has something to say about management of competition. He would like to see more demand pull and has interesting ideas on how the system could be reformed, both to improve incentives and the behaviours of research providers, and to make the provision of policy advice and purchasing more efficient and effective.

In this issue you will find a contribution from James Buwalda, CEO of the Ministry of Research, Science and Technology, that outlines the approaches currently taken by Government and the Ministry in investing in research to improve New Zealand's economy, and discusses the expectations and challenges currently facing New Zealand's research, science and technology sectors.

Steve Thompson, CEO of the Royal Society of New Zealand, gives us a thoughtful personal view on the nature of growth, the role of imagination, and what economists are saying about these subjects.

Sean Devine, research fellow at Victoria University, gives us a high-level critique of the conceptual framework of the science reforms and emphasises the need for greater coherence within the science system. He especially wants a "focus on the health of the whole system", particularly on its vision and purpose.

Nick Allison, Group Manager at the Foundation for Research, Science and Technology, gives us insights into what it is like to be at the coal face of funding and investment, with a mandate to initiate new strategic directions. He critiques the system that implemented the Foresight strategies and observes that no organisation appears to own the strategies or be accountable for achieving them. For Nick, the problem appears to lie in a lack of clarity surrounding strategy formulation and implementation.

Anthony Scott, of ACRI, provides a high-level discussion on how to achieve an effective performance-based science system that will benefit the nation over the long term.

Ian McIntosh, of Victoria University, discusses the complexities of investment decision-making, arguing that diversified decision-making is likely to lead to better investment decisions than centralised decision-making.

Janet Grieve, council member of the New Zealand Association of Scientists, points out that there are covert, as well as overt, strategies that can be understood with hindsight. For her, Government's apparent intent to reduce the quantum of core environmental research (in many cases by more than 20% by 2005/06) has been obscured by a redefinition of core environmental research through including both energy research and research intended to mitigate environmental damage caused by industry.

Neville Jordan, Principal of Endeavour Capital Limited, and Paul Atkinson, scientist and manger at AgResearch, discuss the role of development and the future role of discovery in ensuring that there actually is something to develop in the future! They suggest that the rather flat international publication rates achieved by CRI researchers, in spite of rising inflation-adjusted revenues, reflects Government's withdrawal of funding for discovery in order to fund development. They reinforce the notion that the greatest returns from investment in R&D (social rate of return) often come from work not targeted directly for private appropriation.

Cath Kingston, of HortResearch, gives a scientist's interpretation of what it is like to be at the research coal-face in the present system. Nigel Kirkpatrick, CEO of Industrial Research, and Paul Callaghan, Director of the MacDiarmid Institute at Victoria University, each give accounts of institutional responses to current Government policies.

Andy Reisinger, Ministry for the Environment, discusses climate change policy and research, drawing parallels with ozone policy and research, and indicating the key lessons we can learn from ozone work that can be applied to climate change.

Suzi Kerr of Motu Research (a private research organisation, specialising in economics, policy research and climate change policy and research), provides an informative discussion of the contributions to be made by first class policy research to New Zealand's innovation system.

Today, New Zealand appreciates more than ever before the value of investing in a first-class research infrastructure, both for economic and social reasons, and because it is an integral part of our culture. We are rapidly gaining a better understanding of the drivers and opportunities facing us and, if we now apply the lessons we have learned, then we can look to the future with confidence.

David Lillis
Guest Editor

Greater expectations

James Buwalda
Ministry of Research, Science and Technology, Wellington

Across Government, the business community, and the general public, research, science and technology (RS&T) are experiencing greater recognition than ever before. More people are realising the important role that RS&T has to play in the many different areas important to New Zealand's future. One example – science played an important part in last year's general election. Science in New Zealand is growing up, coming of age, if you like, and it is now up to all of us to follow through on this momentum, to build on our strengths and keep striving for excellence.

We can be proud of our high quality researchers. Statistics show that scientific output is high (we're near the top of the OECD in terms of research papers produced per dollar spent), quality is high (citation rates for these papers are high), and connectivity is high (shown by high rates of international co-authorship). But some real examples might tell a better story than the simple statistics:

(i) AgResearch is amongst the first and best in the world in transgenic cloning of mammals. A recent paper in *Nature* described how their technologies might be used to manipulate the composition of milk.

(ii) Pulse Data International is a Christchurch company that used Technology New Zealand funding to develop BrailleNote – a portable note-taker for the blind that can interface with standard office software on a PC. This product is now being sold internationally.

(iii) Researchers at the Institute of Geological and Nuclear Sciences are analysing hydrothermal plumes from under-sea volcanoes in the Kermadec arc, with a view to identifying base metal deposits in New Zealand's EEZ. This work could open up new commercial opportunities in our marine environments.

(iv) Dr Peter Hunter's group at the University of Auckland, working in collaboration with medical researchers in New Zealand and overseas, have developed complex computer models of muscle biomechanics. These models can be used to assist in the development of new health-care therapies.

The importance the Government places on RS&T is clearly signalled in its growth and innovation framework, released in February last year. In this framework, RS&T is the ideas generator that produces new products and processes to improve existing businesses and create new industries.

More and more key areas are requiring input from RS&T - biotechnology, sustainable development, biosecurity. RS&T is expected to both respond to and have an influence on these issues, providing the information and the tools for those working in these areas.

The RS&T sector is focusing more on equipping the country to be effective internationally, placing increasing importance on world-class research that is recognised as the best chance of getting valuable outcomes.

Increased recognition leads to increased expectations of what RS&T will deliver. RS&T is experiencing greater and greater demand both in the quantity and quality of results. In the future, we can expect these demands to keep increasing. How will the RS&T sector respond to these changing expectations?

Last year, the Ministry of Research, Science and Technology (MoRST) identified a need for a strategy statement that would recognise the changing expectations and direct the sector's continuing evolution. Something that would make sure that all of us involved in science were moving in the same direction and working together. Our overarching goal was to build a high performing RS&T system, able to meet the demands placed on it.

From the outset, we realised that we couldn't do this on our own. If we wanted to shape the way the sector was going we needed input from all those in the sector, identifying what the main issues were and how they saw the way forward. We wanted to get input from a wide range of people as possible.

The challenges ahead

From all our discussions, three main challenges emerged:

- Uncertain directions

Dr Buwalda has been Chief Executive for MoRST since 1996. During this time he has focused MoRST's efforts on finding ways for New Zealanders to get more benefits from research and innovation. This has involved both promoting the concept of a knowledge society and developing ways of turning this concept into reality. Current projects include developing a strategy to enable New Zealand to proceed with caution in biotechnology, designing new ways to fund early-stage commercialisation, fostering dialogue about RS&T within the wider community, and linking RS&T to government strategies ranging from growth and innovation to biosecurity.

Dr Buwalda has a background in agricultural research. For 17 years, he was a research scientist, with the Ministry of Agriculture and Fisheries and HortResearch. While at HortResearch, he also spent time as a Science Manager, with responsibility for developing science strategy. Before becoming its Chief Executive, Dr Buwalda was the Chief Policy Adviser for MoRST.

- Volatile environment
- Low business investment.

Uncertain directions

There are many competing demands for the attention and resources of RS&T — a symptom of greater expectations. This can cause diffusion of effort and can be confusing when decisions need to be made. If we try to do too much we end up doing nothing.

Volatile environment

There is a high level of contestable funding in the RS&T system. While this means that changes in the Government's investment priorities can be quickly implemented, it can also create a volatile environment, undermining the core capability that is needed for long-term research. A particular challenge is to recruit and retain the top researchers who build the research teams that drive the most productive research.

Low business investment

New Zealand businesses do not invest enough in research and development. Reasons for this low rate of investment include the:

- structure of the New Zealand economy
- lack of business acumen to commercialise intellectual property
- poor connections between RS&T providers and potential users.

Coupled with this low business investment is the low rate of commercialisation of publicly funded research. We need to increase the range of benefits we get from the government's investment.

The solutions – *The i³ Challenge*

To overcome the challenges described above there are three corresponding solutions:

- Focusing **ideas** on national needs
- Driving **innovation** through strengthened capability
- Generating **investment** to extract greater commercial value.

Ideas

To cope better with the many different demands placed on it, the RS&T sector needs to be able to identify and align with those areas that are of national importance. We need processes and systems that will allow those involved in RS&T to identify how RS&T can best contribute to new government strategies and ensure RS&T purchasing plans support national needs.

Innovation

We must strengthen the capability of RS&T to make certain that the flow of new ideas and knowledge is sustained. This will require us to look for more stable ways of funding capability and work with Mori and the social research community to improve capability in these sectors. We want to support those world-class researchers who perform at the cutting edge.

Investment

New Zealand needs to build relationships of mutual understanding between researchers and businesses — promoting more partnerships and co-investment. We will also look to increase funds for commercialising research, including encouraging public research institutions to act as early stage investors.

The Minister of RS&T launched ***The i³ Challenge***, outlining these issues and responses, in February 2003 (go to www.morst.govt.nz/publications/i3challenge.html to get your copy). We are now developing more detailed work plans to address these themes. This will involve work led by MoRST to develop new policies, as well as work led by others in the RS&T sector, in response to ***The i³ Challenge***.

Our policy work will involve activities alongside each of the three proposed solutions:

Focusing IDEAS on national needs

We will put in place better processes for informing the RS&T sector about new Government strategies, involving the RS&T sector in shaping these strategies, and getting commitment from the RS&T sector to respond to these strategies. Some of the important areas of Government strategy where RS&T is relevant now include growth and innovation, sustainable development, climate change, biotechnology, biosecurity, bioprospecting and oceans policy.

We will work closely with other parts of government to ensure strong linkages between their portfolio interests and the RS&T sector. We will also ensure that purchase agents (such as the Foundation for Research, Science and Technology and the Health Research Council) pay close attention to these national needs in their work.

Driving INNOVATION through strengthened capability

We need to develop a shared understanding of what we mean by *capability,* and then provide more stability for some important long-term capabilities. This work could lead to some changes in funding processes over the next couple of years.

We need an appropriate balance between competitive funding for identifying new areas of interest and negotiated funding for supporting agreed areas of importance. This might mean that we need to change some of the criteria for some of the funding instruments, or change the balance of funding between the various instruments we use. But, in making any such changes, we cannot compromise quality.

Generating INVESTMENT to extract greater commercial value

We are already quite active in this area – finding better ways to ensure that our world-class research generates value. Over the last couple of years, new initiatives in venture capital and research consortia have been introduced. We are looking at further changes in terms of expectations on purchase agents and research providers.

For example, Crown Research Institutes have been given clearer signals about the risk profile involved in being more commercial. We want to further emphasise and encourage their role as catalysts for a growing economy.

Much of the response to ***The i³ Challenge*** can come directly from others within the RS&T sector. Organisations such as purchase agents and research providers are being encouraged to pay close attention to the issues and propose responses in their strategic and business planning processes. As these various organisations align their efforts around ***The i³ Chal-***

lenge, we should see a significant lift in the overall performance of the RS&T sector.

The i³ Challenge isn't something we each work on independently. It is a challenge to the entire RS&T sector. It represents a great opportunity to work collectively to lift the contribution of the RS&T sector to New Zealand's future development. Actually, a lot has already happened over the last six months consistent with the directions outlined in ***The i³ Challenge***. For example, there is a lot more dialogue between the various parties in the RS&T sector, and strategies coming out of Government now have a lot more to do with RS&T than we typically saw a couple of years ago.

I look forward to further progress in the contribution that the RS&T sector makes to New Zealand's economic, social and environmental development. We have some excellent foundations in place – good people and high quality research. As we focus ideas more on national needs, drive innovation faster through strengthened capability, and generate increased investment to extract greater commercial value, we will build a truly world-class RS&T sector.

A systems look at the science reforms

Sean Devine
Victoria Management School, Victoria University of Wellington

Introduction

Following the science reforms in the early 1990s, there was significant optimism about the future of science; an optimism that now seems to have been misplaced. The reforms assumed that, by bringing market discipline into the research environment, better alignment between researchers and end-users would emerge (Devine, 1997). It was also assumed that transparency and focus would be enhanced by separating the functions of Government science departments into agencies such as:

- the policy agency, the Ministry of Research Science and Technology (MoRST);
- purchasing agencies such as the Foundation for Research Science and Technology (FRST) and later the Royal Society and the Health Research Council;
- the Crown Research Institutes (CRIs) that, with other providers, competed for research funds;
- the CRI ownership agency.

At the time, the conceptual map shaping the science reforms had only a few simple directions. Now it is clear that the science system, while needing reforming, was not the only weak link in the innovation chain. A culture that saw economic growth primarily in terms of efficiency and good business practice, and that saw little benefit in private sector R&D, was significant. This paper looks at what has been learned in the intervening years and how we can improve on the simplistic conceptual map to better manage publicly funded Research Science and Technology (RS&T).

The science community itself failed grasp the significance of the reforms. Some challenged the reforms[1] while others, including the Royal Society and academics, supported the reforms for opportunistic reasons rather than conviction. Indeed, the Royal Society, with its access to Cabinet papers and ability to advise Government, could have positively influenced the direction of the reforms. While today the Royal Society is in a better position to contribute to RS&T policy, it will need to develop robust processes if it is to get 'buy in' from the research community.

Limited conceptual framework

It needs to be said that the science reforms delivered a system that was superior to its predecessor. The elimination of useless research (about 20–30% of that previously funded) inevitably lifted the quality and the alignment of the research actually funded. Today CRIs are successful businesses, much better aligned with their end-user sectors than were DSIR or MAF. CRIs also earn significant overseas revenue – about half that of the high-profile organics industry – which suggests that New Zealand could be an international provider of research services.

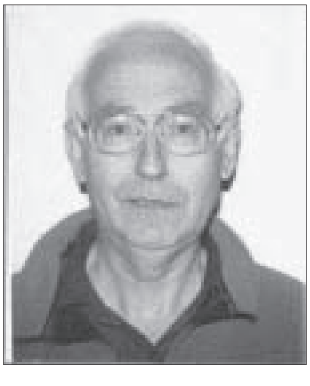
However, the key problem with the reforms was that they were undertaken within a one-dimensional, 'market-solves-all' framework. This view, by failing to adequately recognise that economic growth is not just about efficiency, was limiting. Some simple issues took years to resolve. A key example was the Catch 22 of appropriability: "When, if ever, should the Government fund research where the private sector or end-users might gain some direct benefits?" "But why fund the research if no one benefits?"

Conventional economic analysis provided little understanding of how RS&T transforms an economy, and therefore tends to undervalue the benefits of publicly funded research. It took some years before the insights of Endogenous Growth Theory (Romer, 1990) became part of the New Zealand policy framework. This view, which is an extension of neoclassical economics, recognises that knowledge is the driver of economic growth, creating platforms of new economic opportunity. However, while affirming the importance of knowledge, Endogenous Growth Theory is still trapped within an equilibrium framework[2]. A more realistic approach is to be found in evolutionary economics (Ziman, 2000). Without the understanding of the pervasive nature of scientific-led innovation, it is difficult to realistically evaluate publicly funded research, as the following example illustrates.

The value of New Zealand's lead–rubber bearing technology, to protect structures in earthquakes, can be measured in terms of royalty returns (miniscule), or in terms of the value of

[1] The persistent dissenting voice of the NZ Association of Scientists and the Institute of Agricultural Scientists probably contributed to a more human face to the reforms.

[2] A real economy is far from equilibrium and growth drives it further off equilibrium.



Sean Devine spent 20 years as a research scientist, and then a science manager, in the Physics and Engineering Laboratory, DSIR, working in condensed matter physics. With the funding cuts to science in the mid-1980s, Sean studied economics on the grounds that "if you can't beat them join them" and later became manager of the Public Good Science Fund at FRST. After five years in that role he took up a position as Executive Director of the Association of Crown Research Institutes. He recently moved to Victoria University as a Research Fellow, focusing on the economic effects of technological change.

products made in New Zealand (modest)[3]. However, over $1 billion of these have been produced worldwide. Furthermore, the value in terms of reducing the cost of protected buildings is significantly greater still (otherwise the technology would not be used). Much harder to measure, but even more significant, is the security the technology brings to hospitals, government buildings, etc., which are able to function, and the reduced loss of life, following a serious earthquake. A simplistic evaluation would underestimate the value by many billions of dollars.

Systems issues arising from the policy/purchaser/provider, split were not adequately recognised. While the science reforms were intended to align policy, research and end-user groups to deliver national benefits, because no single organisation had the ability to manage the system as a whole, the coherence that was necessary for an effective RS&T system did not emerge.

The incoherence became apparent in CRI behaviour. While an ideal market is win:win (everyone is better off by participating), as a tool to align scientific research with national needs, the market acts as a club. For example CRIs were forced to depend on a monopoly supplier (FRST), undermining the market win:win principle. Furthermore, as CRIs were inappropriately staffed and funded for the expectations placed on them, for long-term survival they needed to reduce dependency on FRST, and fire staff. Putting it in its bluntest form: "Why should a CRI go the extra mile to involve others in commercialising, or by collaborating with competitors, when to do so would threaten the viability of the organisation, and jobs for its staff?"

Furthermore, a CRI is obligated to generate a significant rate of return on assets, providing a disincentive for the CRI to create value in new businesses, to expand into new areas, or to provide free public benefits. The value the CRIs create, in contrast to the profits they make, is virtually unrecognised in CRI performance.

Need for an holistic approach to economic transformation

The clear weakness in the science reforms has been the lack of focus on the health of the whole system. All the easily made efficiency gains in funding RS&T have already been made. Now, the important determiner of effectiveness is not to do with competition, CRIs or even the publicly funded research process: it is to do with making the whole system work coherently. Ackoff (1994), a systems 'guru', has stated: "It can be shown that when each part of a system taken separately is made to perform as well as possible, the system as a whole **cannot** perform as well as possible"

The Viable Systems approach (e.g. Beer 1985) is a useful framework for organising thoughts about the place of RS&T in economic transformation. This model can clarify the purpose of RS&T within a wider innovation system and provide insights into how the components can align and how the system can respond to the external drivers that impact on the system's viability. When applied to RS&T and innovation the model asks (Devine, 2002):

- What are the system's vision and purpose, and what strategies will achieve the system aims?
- How can all players within the system – researchers, businesses, venture capitalists, financiers and educators – be aligned to achieve the system's purpose?
- How can the system generate the necessary variety (or in ecological terms, diversity) to adapt to external threats and opportunities?
- What gaps exist in the system and how might these be filled?

System's vision and purpose

Defining a vision and purpose for something as diffuse as research-led economic transformation is difficult. Nevertheless, a good start has been made. The Prime Minister (Clark, 2002) has articulated a comprehensive vision and sense of purpose for New Zealand's innovation system. However, a democratic Government cannot impose this sense of purpose on the nation. The Government's role is therefore in setting strategic directions, facilitating better alignment of the system players with the system purpose, making the system work coherently and filling gaps – in particular encouraging sources of variety or diversity essential for the system's long-term performance. Government's role is therefore in addressing system failure, of which market failure is but one example.

However, Government alone cannot define the system's purpose; there must be 'buy in' from society as a whole. For this to happen, there need to be effective means of generating societal debate on key issues. The Business Roundtable has been, to some extent, such an organisation in the past. However, because its worldview is limited primarily to good business practice and efficient use of resources, it has little to offer on economic transformation. But, with a little loosening up, and with new members from emerging sectors becoming more prominent, the Business Roundtable could take a greater leadership role. Nevertheless, for a robust debate, other business organisations, academics, unions, and the Royal Society also need to engage in generating strategic discussion.

Alignment of system players to the overall system purpose

A key Government role is to bring about system coherence to mesh its research funding into the wider innovation system. Because Government cannot command an economy, it must judicially use the tools at its disposal to bring about better alignment of players: business, financial institutions, educational and training institutions, research organisations, and opinion leaders. There are a number of approaches:

- Provide leadership in articulating directions and providing encouragement and incentives to embed these directions in system behaviour.
- Encourage societal debate about economic directions as has been mentioned above.
- Facilitate a deeper cultural alignment with the directions.
- Identify and fill specific systemic gaps.

[3] The returns to New Zealand were limited because the Development Finance Corporation, who held the patents on behalf of the Crown, focused on cash returns, not wealth creation.

The incentives and signals provided by Government's priority process is a key tool at Government's disposal. In recent years, this tool has become muted and, as a consequence, system coherence has declined. Strategically targeted tax[4] and business growth schemes, etc., all help to align system players with government directions.

The major need, therefore, is for a deep cultural change within New Zealand at all levels. Opinion leaders need to move beyond a focus purely on business efficiency and develop technological literacy. Perhaps even more critical is the need for wider society to gain some understanding that economic growth does not just happen and reach a position where the value of risk taking and innovation are recognised.

The Foresight Process and the Knowledge Wave conference were less about identifying specific actions but were more about developing societal discussion about directions and opportunities. However, less than 5% of the attendees at the first Knowledge Wave Conference could be considered entrepreneurs. Unless the voice of the emerging economy is more prominent, future conferences are in danger of becoming talkfests.

Just as the business community needs to become technologically literate, with greater levels of technical and scientific qualifications, the science community also needs to change. Unless scientists become literate about business and technological opportunity, they will contribute to the marginalisation of research. Scientists need to understand market economics with its weaknesses and be aware of the developments of Endogenous Growth Theory (Romer, 1990) and Evolutionary Economics (Ziman, 2000).

Strategies and structures to generate diversity

Just like an ecological system, variety or diversity is key to economic viability. Where any system cannot generate sufficient diversity deep within itself, strategic interventions become necessary. Conversely, in the innovation system, where strategic interventions are limited, enhancing diversity is critical. This diversity must be through allowing new ideas and new processes to emerge, some through RS&T, some through learning by doing, some though adapting overseas technology. Creating diversity also involves enhancing new networks and new structures in education, business finance, or the creative enterprises. Most of the needed diversity will arise outside of the more traditional economic sectors. Who would have dreamed even ten years ago that the film industry would emerge as a key earner?

Government has too little information to pick winners, but instead, must create an environment where diversity in the innovation system is encouraged at all levels – not just research. Particularly important is encouraging a risk taking and entrepreneurial culture.

The comparatively low level of private sector R&D is a key indicator of a New Zealand strategic weakness. However, where private sector R&D is significant, New Zealand is highly competitive. The quickest way to increase private sector R&D is to encourage these areas, rather than 'flogging a dead horse' by trying to increase R&D in more traditional areas. Emerging innovative, research-intensive enterprises can be encouraged through:

- the support structures of Industry New Zealand and business mentoring schemes;
- research technology schemes such as those offered by FRST;
- facilitating the development of the necessary financial markets, e.g. venture capital markets, angel investors, etc.;
- proactive tax regimes for R&D and patenting;
- encouraging incubators, networks and clusters.

RS&T operational issues

Structural issues

A key weakness in the current system is the misalignment of policy, purchase and provision of RS&T. The simplest solution is to join MoRST and FRST to ensure overall system coherence. Policy will be informed by information flows from end-users, while sectors and purchasing decisions will be more clearly tied to government directions. Where mismatches between purchasing and policy occur, corrections can be rapid rather than taking years to sort out. It will also be much easier for high-level priorities and investment portfolios to be clearly defined and a robust economic capability can be supported using the resources of both organisations.

There are also good arguments for the ownership of CRIs to be part of the same structure to resolve conflicts between purchasing goals and ownership goals.

If the above suggestions are impracticable, integration could be improved through having an overarching Board monitoring all aspects of the RS&T system, or at least by ensuring the CEO of MoRST is a member of key Boards such as FRST.

The conclusions are that, with the key agencies all working under the one umbrella, science policy will be able to set coherent and long-term credible directions to reduce the instability of rapid change.

Funding processes to generate research diversity

A key understanding is that it is very difficult for purchasing agencies to pick winners. It is far easier to identify losers – those projects that, but for a miracle, will never succeed. The primary criterion of government funding is therefore to eliminate these. As this has mainly been achieved, public research funds should now focus on creating an environment where diversity is encouraged, whether at the basic end, the middle of the spectrum, or the commercial end.

The key decisions to be made in funding of RS&T revolve around:

- understanding that research is a long-term enterprise and any investment relying on rapid changes of direction will divert resources and delay the delivery of benefits;
- understanding that closing research directions is a cost to the system as a whole and should only happen when it is clear that the returns from diverting the investment will cover the cost of change;[5]

[4] Where R&D is treated in the same way as bricks and mortar for tax purposes, our economy will be locked into slow growth regimes.

[5] While there is a good argument that New Zealand publicly funded research overemphasises the primary production sector, the research is nevertheless returning benefits. It is not at all clear that shifting funding to, say, information and communication technology, will more than outweigh the costs of change.

- understanding the trade-off between generating diversity and maintaining and developing necessary human capital;
- understanding how to align research with national directions, while keeping transaction costs minimised.

Evaluation of research should become the key determiner of future funding, and funding changes should be managed, not through a competitive process (except for new funding), but through negotiations with research providers.

Human capital

After the Second World War, Germany rapidly developed economically because the human capital was not destroyed, even though its physical capital was. Human capital, embodied in the people with the skills and 'knowhow' is key to economic development. However, human capital is a system requirement and includes the research scientist, the risk taker who moves between organisations to implement emerging ideas, and those with entrepreneurial, financial or business skills essential to a knowledge economy.

Anything less than providing a stable environment for researchers to exploit their skills will lead to an underperformance of the whole innovation system. Currently, while most of the high-performing scientists are still employed, many have a continual fear that they will be next to lose funding. The kind of people New Zealand needs will not stay in such an environment. However, more than stability is required. Human capital needs to be nurtured. For example, there is a serious shortage of the business skills required for the emerging economy. While there is plenty of experience in traditional business, this experience (like that of cavalry officers in the Second World War) is of little use when the game changes (tanks dominate strategy).

Human capital also needs to be mobile, moving from research to new enterprises to business and back again. This means that CRIs, research associations (RAs) and universities will need to provide safety nets for risk takers and support incentives for researchers to be mobile. Programmes for sharing in intellectual property, and encouraging shared industry/institute employment, secondments, and transferability of superannuation are all important if research scientists are to be encouraged to transfer their knowhow to benefit the nation.

As Universities are a source of great diversity in research, it is particularly important that this diversity is captured by the system, particularly when universities cannot commercialise directly. Key to achieving this is to encourage better flow of staff between universities, CRIs and RAs and by joint research programmes. There would be advantages if the major CRI research laboratories were based on university campuses with staff having joint appointments or being seconded to cross institutional boundaries

CRIs

The current system expects too much from CRIs. Not only are they supposed to undertake world-class research in a high-cost (to CRIs) and risky funding environment, they also take most of the blame for inability of the nation to harness the benefits of publicly funded research. The current system forces CRIs to put their own interest above that of the nation. Therefore they need the incentives and flexibility to focus on commercialising research, for example:

- to make it easier for staff to invest in spin-off companies;
- to use a variety of mechanisms including joint ventures, shareholdings, research agreements with private companies to encourage commercialisation;
- to allow CRIs to commercialise where local firms lack capability in implementing leading-edge technology;
- to allow CRIs need to use public funds to bridge the chasm that exists between a research project's success and the level of development needed before the private sector can take a business risk with the opportunity.

If CRIs are to behave in the optimum manner, the competitive pressure needs to ease by funding adequately and compensating for the weaknesses in the purchasing market. A major opportunity would be to increase core funding (ex NSOF) for CRIs to 50–70% of their public funding, so that contestability exists only on the margins. This would reduce transaction costs, decrease risk, and create the freedom for CRIs to behave in the national interest in their commercialising and risk taking behaviours. More important, by reducing the resource pressure, the nations best scientists can do what they are good at- scientific research, rather than struggle to chase funds where, at best, they will not lose any.

Both core funding and contestable funding should be targeted towards areas of national priority. However, there should be a greater focus on programme and provider evaluation. If concerns arise over the effectiveness of core funding, these should be implemented through the ownership route, which in this model will be aligned with Government directions.

Environmental health and social research

Many of the points about economic transformation also apply to environmental health and social science research, e.g. alignment of players, clear priorities, relationships with end-users, etc. However, because the stakeholders are not as diverse and there is a common understanding of purpose, the current structures for both health and environmental research may not need much change.

However, social science research is delivering below its potential, as the historic levels of investment are far too low. Some reasons for this are:

- Historically there have been no large social science research institutes (such as MAF or DSIR) with the ability to develop strong cross-disciplinary teams to attack some of the most important social problems. As a consequence, the research is fragmented.
- Socially oriented departments spend abysmally low sums on research even compared with the much-maligned private sector. Remembering that New Zealand spends something like \$11 billion per annum on social service delivery, even 0.5% of this (about the level of the much maligned private sector R&D) would make some \$55 million research funds available annually. It is difficult to believe the effectiveness of social service delivery could not be enhanced in a few years with such expenditure.
- Decision makers are wary of social research because (with some justification) they see it as more ideologically driven than research in the natural science areas. One only needs

to look back at what happened to the Royal Commission on Social Policy's report to get the picture.

- Different social science methodologies have different perspectives, e.g. an economic approach to poverty, focusing on education and skills, is likely to draw different conclusions from a postmodernist approach, focusing on power structures.

The last of these indicate the need for social science research to provide a contestable pool of ideas to allow decision makers the capability to balance alternatives.

Conclusion

The view expressed in this article is that RS&T policy should focus on making the whole system work. Many of the concerns raised are already being implemented because decision makers perceive weaknesses, but they have a limited framework in which to work. Unless some of the systems issues are addressed, there can be little confidence that increasing public RS&T expenditure overall will significantly improve outcomes.

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How we can improve the performance of New Zealand's science system

Peter Winsley

This article was written to stimulate debate, and reflects the personal views of the author only.

Introduction

This paper argues that there is substantial room to lift the performance of New Zealand's public science system by addressing structural and systemic issues, modifying the science funding system, changing the incentives and behaviours of science providers such as CRIs, and giving university post-graduate research a more central role. The paper essentially addresses the science funded through Vote: Research, Science and Technology (Vote:RS&T). It focuses primarily on the science system's contribution to industrial and economic outcomes. However, many of the arguments apply equally to environmental research, and to some extent to health and social research.

Structural and systemic issues

New Zealand's science system is to a great extent a product of institutional economic and neo-liberal thinking of the 1980s that argued that policy and operations should be separated to avoid conflict of interest and capture. It contended that public service-oriented organisations were inherently inefficient and could only be made to perform if they were restructured around the model of the private firm.

While a substantial body of economic opinion favours separation of policy and operations, there is no robust case in economics supporting a separation between policy and funding allocation. The result of the separations within the structure of the science system has been information asymmetries and relationship management problems. MoRST has been deprived of the uncodified and operational learning from science funding and operational functions, while FRST and science providers have not had an adequate knowledge of, or input into, wider government policy and other processes.

The structure of the science system impedes the free and rapid flow of tacit and uncodified information and learning. It also locates decisions at the wrong levels. Detailed, input-oriented decisions, for example on post-doctoral and other fellowships are generally best made by science providers and users, based on their long term strategic decision-making, rather than by agencies such as FRST that are not close enough to how the needs of users and the underlying science are changing. Likewise, peer review decisions on science excellence are in most, though not all cases, best devolved to science providers rather than made by central agencies.

The above structural and systemic problems have led to ad hoc interventions to try and patch up problems without dealing with the underlying causes. Non-Specific Output Funding (NSOF) was established as a safeguard against 'purchaser failure' by FRST. The Marsden Fund was established in reaction to FRST's strong focus on user links and relevance of research, while the New Economy Research Fund (NERF) was set up primarily to give researchers the freedom to develop their own research opportunities without being constrained by a rigid output class system. The Pre-Seed Accelerator Fund addresses a failure in applied and developmental research that exists only because of inflexibility in the management of existing funding schemes.

The proliferation of funds and new initiatives has generated excessively high transaction costs and is becoming increasingly unwieldy. Funding proliferation can also mask policy drift and opaque intervention logic. For example, there is at least some danger that Technology for Business Growth (TBG) will drift into an input-oriented fund for CRIs, or at least their subsidiary companies, rather than being driven by the commercial imperatives of companies. Similarly, the Maori Fellowships scheme could drift away from its focus on building Maori skills through science that is universal, international, cross-cultural and secular.

There are now scientists who are funded from several different sources, leading to considerable uncertainties and excessive transaction costs. While it can be argued that the proliferation of schemes has allowed more flexibility and differentiation in research investment, the benefits of differentiation can be achieved by simply widening the scope of a smaller number of funds and allowing their focus and operation to be shaped by interactive engagement between providers and users.

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The science system as currently structured generates excessive overhead costs. In the former DSIR the main overhead was its Head Office, which was very lean until the last few years leading up to the science reforms when it grew dramatically to cope with rising compliance and other demands from central government agencies. Since 1989 we have seen the creation of MoRST and FRST, boards for nine separate CRIs, the Association of CRIs, commercial and other support staff, and a new science funding capability in the Royal Society. FRST has grown dramatically to accommodate more labour intensive and 'hands on' interventions, while MoRST's staff levels have grown as it has spread itself thinly over a host of issues, some of them peripheral and others best left to other agencies. MoRST and FRST collectively now have the staff and budget of a medium-sized research institute. It is argued that there are some top-level scientific people now working in policy and administrative roles who, while very able in their current positions, could probably create more value for New Zealand by working at the sharp end of the industrial economy or in the research institutes underpinning it.

However, the really major overhead that is difficult to quantify is the time that scientists spend in organising bids and in meeting compliance requirements. This typically takes up a large part of more senior scientific staff time, and above all it focuses their intellectual energies on the needs of the central agencies, not the needs and opportunities of the users.

There are a number of structural options to address the problems canvassed above:

Option 1: Transferring science funding functions to operational departments

Transferring public funding of research to operational agencies such as MAF, the Ministries for the Environment, Economic Development, and Trade and Enterprise, and disestablishing MoRST and FRST would, on the face of it, have several big advantages. It would position research investment at the core of departmental responsibilities and make it integral to their functions. It could improve the strategic focus and relevance of the research and lift uptake and adoption of research results, especially where operational agencies such as Trade and Enterprise approach things from an outcome, market demand-pull rather than a science push perspective. There would be potential to cut overhead costs and transfer the savings to science.

A variation on this approach would be to loop public funding through operational agencies and industry bodies (such as Dairy Insight and Meat New Zealand) and let them manage the research funding to ensure more strategic focus and relevance. An argument against this scenario is that the research could become too short term in focus. However, it can be argued that the way New Zealand's public science system works in practice is effectively more short term in focus than much of New Zealand's business sector.

Operational government departments tend to be driven by short term political priorities and would struggle to develop both a long-term approach to research funding and the skill sets needed to manage and evaluate long term research investment. In the past some science funding transferred to operational departments ended up being diverted to non-research activities. However, this predated the Public Finance Act which, through the output class framework, provides some defence against such funding diversions.

Option 2: Merging MoRST and FRST

In my view, New Zealand needs a specialised agency that gives science a dedicated voice at the Cabinet table. I favour merging MoRST and FRST to create a new, slimmed-down strategy, policy, funding and evaluation Ministry to manage the existing Vote: RS&T, including the Marsden Fund[1]. Most of the operational detail (e.g. fellowship schemes, international science liaison, most peer review, sector-specific strategy and portfolio development etc) would be devolved to the science providers. This devolution would maintain the policy/funding and operational split, cut out one link in the chain, reduce information asymmetries, and allow multi-million dollar administrative savings to be transferred to science.

There is however an interesting variation on this option which would be to transfer the strategic and policy functions of MoRST to FRST, thereby creating an entity that would combine strategic policy with the funding allocation roles to give effect to it. The residual MoRST could be converted to a small team within the Minister's office, focusing primarily on Ministerial support and advice, perhaps with a Chief Scientist capability.

Science funding system

I contend that the three key problems in the science funding system are the lack of strategic direction, the focus on input-oriented or science push research, and the way competition is managed.

Strategic direction for funding

Long-term science priority setting has always involved a tension between the inherently long timeframes of science and the flexibility and dynamism needed as the science, the economy and society changes. Science priority setting processes in 1992 and 1995 were contentious and difficult, were not always well supported analytically, and were hampered by rigidity in the output class system.

The Foresight Project in 1997-99 aimed to develop outcomes for New Zealand that might give direction to public research investment. Even if Foresight had succeeded, by the time such long term planning exercises are completed, the world, and fast moving sectors and science, have moved on. The Foresight Project, the subsequent *Blueprint for Change* document, and the restructuring of output classes had the effect of replacing long term priority setting with short term and often annual directions and fine-tuning. This effectively meant that FRST has been given very wide flexibility to invest as it sees fit, and in practice this may well have led to better *short term* funding decisions than if it had been constrained by a rigid output class system and inflexible long term priorities.

However, some good funding decisions within a short term, contextually-constrained and science push framework may not lead to good long term outcomes, especially if the user/provider learning relationships are not in place and the long term, cumulative and path-dependent dynamics of scientific and tech-

[1] There may be arguments to transfer the Marsden Fund to the Tertiary Education Commission and focus it on leading edge university research with a strong post-graduate component.

nological change are not understood and managed. As an example, New Zealand may lose its competitive advantage in fields such as agribusiness and spend large sums on 'new economy' research to find that it leads nowhere (even Isaac Newton got burnt by the South Seas bubble!).

Without a long term direction the science funding system can rapidly lose its way, and this appears to be happening already. While the change of government at the end of 1999 led to rather more Ministerial intellectual leadership, and provided some clear new directions in areas such as climate change and ocean policy, the science system still lacks the long term strategic direction needed to enable a major shift into long term portfolio-level funding.

Long term guidance on science priorities is needed to give some ability to science providers to plan and to form the basis for long term funding, and ultimately to empower the devolution of detailed decision-making from MoRST and FRST to providers and users. This guidance should give direction to science providers and users but not second guess the specific details of the research or the outcomes desired from it. For example, guidance on science priorities could indicate the long term funding for a CRI such as AgResearch, this funding being allocated to the creation of value for its aligned pastoral animal industries. The details of the research would then be worked through between AgResearch and its aligned sectors, and the research itself conducted with loosely structured, but vibrantly dynamic, interaction between this CRI and its user sectors.

Input oriented, science push research

The current structure and modus operandi of the science system is still too supply push and not sufficiently demand pull. Yet if New Zealand is to achieve per capita income growth it must address the demand side. For example, we must foster the growth of businesses that can produce products and processes that people in other countries want to buy, with these businesses in turn creating the derived demand for science and technology and the pull through of young technologists and scientists emerging from our universities.

From 1993 FRST began to place emphasis on user-linked research, encouraged industry strategy development, and grew the TBG programme on the basis of a strong commercial orientation. However, from the mid to late 1990s a number of forces began to pull the science system away from user-linked research. These forces included the establishment of the Marsden Fund and, much later, NERF. More importantly, CRIs moved to reduce their dependence on FRST and industry funders by developing their own income streams, often through seeking to commercialise their own intellectual property rather than encouraging industry to do so. This was understandable, given the uncertainty of public funding, and the concern some CRIs had that the sectors they were aligned to were unlikely to grow and in some cases were perceived by central agencies as part of the 'old economy' and therefore unlikely to attract high levels of public R&D investment.

The Marsden Fund was established primarily as a result of university lobbying for investigator-initiated research that was unprioritised and did not require user links. It reflects a mix of the curiosity and desire to stretch boundaries that is a driving force of societal change, a naive belief in the linear model of innovation, and a certain class-based distaste for utilitarian science: "better to study Latin and Greek than be an engineer on the factory floor". The Marsden Fund has at least deflected criticism of FRST that it is too focused in its funding schemes on outcome delivery and user relevance. However, in my view it would create more value if it was allocated very largely to university research with a strong post-graduate component, with the major focus being human capital creation, drawing on leading edge international research.

The establishment of science push funds such as Marsden and, much later NERF, had some pluses and minuses. The motivation of breaking away from the conservatism of FRST funding (which was after all motivated by a desire to protect career stability) was reasonable, and NERF in particular seems to be releasing some creativity and catalysing some new ideas. However, on the downside it has meant that parts of the science system have drifted away from the interactive relationships and user applications needed to turn research into outcomes. This is likely to be at the expense of innovation and technological learning and knowledge application in existing industry sectors, and in the new businesses and sectors that spin-off or arise from them.

Recent calls for more focus on capability building in CRIs are partly motivated by support for science push and investigator-initiated research. New Zealand must build capability across a wide range of emerging scientific fields, if only to build absorptive capacity to better adopt overseas technology. However, such early stage investigator-initiated research and capacity building should be done largely in universities, especially in their post-graduate research programmes. This is because young people who have done leading edge research and are then mobile in the economy are generally a better investment than CRI staff whose skills are internalised within centralised research institutes. It is the task of universities to build capability and it is the task of CRIs and private businesses to draw on, extend, and to actively marshal that capability and apply it to economic and societal opportunity.

The way competition is managed

On establishment in 1990 FRST managed its funds in a competitive and rather fragmented way. In its very early years it treated funding applications in isolation from each other as if it was managing a fish market, not acting as a long term investor that was mindful of its wider context and learning relationships. This policy reflected a peculiar hybrid of academic belief in science excellence and peer review and neo-liberal belief in the workings of competitive markets.

In effect, in the early years FRST operated a competitive system across the whole of the Public Good Science and Technology (PGST) fund. The result was that the science providers stuck to 'safe science' in order to avoid risk and preserve their funding. FRST's funding conservatism no doubt impeded some *inventive* scientific approaches. However, it did not necessarily impede *innovation* because it did force a focus of scientists on user uptake and application.

The current FRST board continues to struggle with the tension between running a competitive funding system, a contestable allocation system, an investment function, and a stewardship role of maintaining infrastructure, the stability of the science provider system and the staff within it. Given the difficult environment in which it operates, FRST deserves considerable credit for the value it adds to the science system. However, one suspects there are just a few key people in central agencies such as FRST who are holding the science system together, in spite of rather than because of the structure and system in which they work.

Competitive funding of science internationally is typically for 'top up' or additional funding over and above core funding, and it is rare for public research institutes to be required to compete for all their public funding. FRST has actively worked to minimise the instability associated with short term competitive allocation by adopting a contestable, rather than competitive, approach to funding. However, the current funding system is rather mercurial and difficult to plan around, and even the best scientists and research teams can end up being hit by short term funding shifts, and in some cases by straight out accidents.

It is important to distinguish between skills that are generic and mobile and those of high asset specificity[2], because this gives guidance on what fields of research should be competitively funded. In some publicly-funded fields of research scientific skills have very high specificity; that is, their value in their specialised use is much higher than in more generic applications. These scientists are dependent on a government purchaser which is both a monopsonistic buyer and controls the price. In such a market it is unreasonable to expect scientists to sacrifice career flexibility and other job possibilities while devoting themselves to such a specialised career path without being paid either a risk-adjusted premium or given greater job security. Placing funding for such specialised research fields on a competitive basis will, over time, lead to severe recruitment problems, and this may already be happening.

It is entirely appropriate that researchers in universities or other public or private institutes with core or 'bread and butter' funding and/or with skills of wide application should be expected to compete for funds to grow new areas of research. However, publicly-funded scientists, working in fields where the Government is both the sole buyer of their services and controls the price, should be funded on a long term and non-contestable basis, and provided with a life-long career path provided that they and their institutes perform. In effect, we should enter into an implicit contract with such scientists: in return for a high degree of intellectual freedom and confidence of a life-long career path they make a life-long investment in creating their highly specialised skills and maintaining their currency, for what is effectively an average professional income. There is a relatively small number of such scientists; they do not cost much, and there are negligible, if any, benefits from making their work contestable.

However, retaining a substantial element of competition is essential to the science system. Memories of the weak work ethic in some parts of the former DSIR suggest that full bulk funding and an absence of competition can lead to significant performance losses in the science system. It should also be noted that many scientists and science teams in the CRIs have felt empowered by FRST funding for programmes that were not well supported by CRI top management. Some scientists note that before the science reforms some DSIR directors had an excessive degree of power over the course of research and, in some cases, may have stifled important new areas of research endeavour. However, in those times DSIR divisional directors had no boards to be accountable to, and very loose accountabilities to users and to the DSIR head office. Provided that CRIs and other science providers have strong, user-oriented boards, and are required to compete for around 30% of their public funds and for all their commercial funding, the problems of 'lazy and unresponsive' scientists and 'tyrannical and conservative' science directors will remain in the past.

It is proposed that around 70% of Vote: RS&T funds currently allocated to CRIs and research institutes such as research associations should be bulk funded, with the remaining 30% being fully competitive, and especially focused on growing new areas of research. This approach would provide security and long termism for the bulk of research funding. Just as importantly, it would ensure competitiveness and flexibility for sufficient of the funds to fuel much higher levels of innovation than in the current system, where most funds are supposedly contestable and yet where concerns about science stability limit the competitive decision-making, both formally and subliminally. The irony is that the best way to boost the level of competitive innovation and vibrant research approaches may be to remove competition from 70% of the funds, so that the remaining 30% can be unboundedly competitive.

Consolidation of disparate funds is essential to reduce transaction costs, with the resulting smaller number of funds having much wider scope and flexibility, allowing for the devolution of detailed decision-making to the science providers.

The above could translate into the following major public science funds:

A sector or stakeholder-aligned R&D fund

This would essentially be the existing PGST, research consortia and NSOF funding aligned to sectors or other stakeholder groups. It would be allocated to CRIs and other science providers in very large, long term portfolios. Providers would have great flexibility within their portfolios, provided they are closely and interactively linked with user groups that have the incentives and learning and knowledge application capabilities to turn research results into beneficial outcomes.

A competitive/flexible fund

This would essentially be the existing NERF fund and that part of the PGST that is not strongly aligned to a particular identifiable sector or stakeholder group. The fund would be flexibly and competitively allocated to support new research opportunities or priorities. It could also include an element of reward for institutes that have delivered outcomes.

Technology New Zealand and Technology in Industry Fellowships

This would be based around Technology for Business Growth (TBG) and Technology in Industry Fellowships (TIF), with the other elements of Technology New Zealand being absorbed within them. It is suggested that TIF should continue in its current form, while FRST's policy of focusing TBG on increasingly technologically ambitious and large scale projects,

[2]Asset specificity refers to skills of high value in their specialised use but very low or nil value in alternative uses. A person's investment in such skills is irreversible and non-fungible, raising the spectre of 'fire sale' prices for skills not valued for their specialised use.

many of them undertaken entirely within the company, is strongly supported.

University Research Fund

This fund would be made up of the existing university research funds within both Vote:RS&T and Vote: Education (including the Tertiary Education Commission's Performance-Based Research Fund) and perhaps the Marsden Fund, all amalgamated into a research fund that would support university research led by academic staff and with a strong post-graduate component. Such research would in many cases be focused on advanced scientific and technological fields such as biotechnology, nanotechnology, electronics, ICT, materials science etc. It could also include research in more industry-aligned areas such as agribusiness, chemical engineering, wood processing etc. However, academics should be given very wide scope to pursue their own research interests, provided they are leading post-graduate research programmes that create human capital as well as knowledge. The deliverables from this university research fund would be the human capital embodied in young post-graduates who would then take up jobs in New Zealand companies, knowledge, international connectedness and, from time-to-time, spin-off companies that would reflect increasingly seamless boundaries between universities and the wider economy.

Incentives and behaviours of science providers

The CRIs were established as commercial businesses with benefit of New Zealand objectives in their legislation. CRI board members have typically come from the private sector and often have failed to make the switch from the mindset of the for-profit business firm competing in a market to the mindset of a service delivery agency that is there to do what the market cannot do. CRIs have tended to behave as stand-alone business firms whose performance measure is their revenue streams and profit, rather than as part of a system of innovation which delivers wealth creation and other outcomes only when the parts work together systemically.

In response to the incentives they have been exposed to, some CRIs have focused excessively on their commercial returns at the expense of their service delivery to and for their sectors. They have been too conscious of the boundaries between themselves and users, when they should form part of a vibrant Silicon Valley-type cluster characterised by openness and porous boundaries and the horizontal movement of ideas, technologies and people. In the 1990s Crop & Food was an example of an institute with a static or declining public funding base that was nevertheless able to effectively balance a strong user and service delivery focus with on-going financial viability. WRONZ is an example of an industry organisation that has performed extremely well in delivery to users, while also prospering commercially. For long periods a major part of its industry-wide funding was essentially allocated to it on a bulk funded basis. This reflects the confidence the industry has in this institute, its leadership, and its ability to focus on economic opportunity without input from external policy and funding agencies (parenthetically, WRONZ's success also partly reflects its in-house engineering capability that has enabled it to carry ideas through to the proof of concept and prototype development stage).

Over time, most CRIs have sought to create Intellectual Property and commercialise it themselves in order to make them less dependent on FRST funding which they see as static in amount and mercurial in allocation. This has led to the creation of barriers to interactive relationships with industry and service delivery. However, CRI behaviour has simply been a logical response to the governance and funding incentives they have been subject to, and CRIs will not optimise their contribution to the New Zealand economy until these incentives change.

Changing science provider incentives and behaviours

The incentive structures, strategic and policy directions have to change for CRIs to get back to their fundamental role as service providers that exist to do what the market can't do, not what it can do. Their purpose, as well as their ultimate performance measure, must be their contribution to users and stakeholders external to themselves, not their ability to capture returns to themselves. CRIs must conceive of themselves as organic parts of their aligned industry sectors, with no daylight between themselves and users, and with a free-flow of ideas and people. Their formal focus must change to outcome delivery for users, and their commercial earnings should be seen as the condition of continuing to provide that service over time, not as a primary purpose.

The composition of CRI boards will need to change so they are made up of user group representatives with strong strategic skills and an affinity with science and technology. It is essential that user groups are identified correctly. For example, in the case of much climate, atmosphere, marine and other environmental and resource-based research, the Crown (acting as a proxy) may better represent global and New Zealand users than narrowly defined interest groups such as the fishing industry. Senior academic leaders could also have a more prominent role on CRI boards - the contribution of Alan Frampton to Tatua and Colin Maiden to Fisher and Paykel show what is possible when such skills are applied to long term innovation and wealth creation outside the university environment. Commercial and marketing staff in CRIs should be slimmed down somewhat, and there should be more expectations that typical scientists will be working directly and interactively with user groups, with fewer intermediaries standing between them.

Giving a more central role to the universities

A distinguishing characteristic of all high performing OECD economies is that the major part of their publicly-funded research is undertaken in universities, and with a strong post-graduate and human capital development focus, rather than being conducted in research institutes that lack an educational component.

University research that involves post-graduate research students produces human capital as well as knowledge. That human capital is the skills and (often tacit and uncodified) knowledge of students who are engaged in leading-edge research, whose PhDs are marked and often supervised internationally, and who then take their human capital to New Zealand companies and have it extended and shaped by those companies' market knowledge and production capabilities. The undeveloped nature of much post-graduate research effort explains a lot of the shortages of world class skills in many New Zealand sectors, and their inability to generate world-class innovation. Where universities have been the dominant provider of publicly-funded research, such as in IT and medical research, the results have often been very impressive. There is no question, for example, that the vibrancy of New Zealand's IT sector results primarily from the number and quality of IT post-graduates from New Zealand who have participated in university research, or at least drawn on the knowledge created by academics engaged in such research.

Publicly-funded research aligned to differentiated sectors with a strong human capital component should be done largely in universities. At the same time, most environmental research and research in more homogenous sectors such as agriculture and forestry is best suited to the CRI structure and should be properly and securely funded to reflect their importance to New Zealand. The discounting of agricultural research in particular reflects an archaic view of the agricultural sector as part of 'the old economy'. It is hoped that we have learned from the dotcom and Nasdaq crashes that all technologies and industries obey the laws of economics, and that people will still be paying premiums for quality food and fibre products when Nokia cellphones are a dime a dozen.

Concluding comment

There is considerable potential to lift the contribution of the public science system to New Zealand if the above proposals are implemented. They would help rebuild the morale of the science community and revitalise links between public science and users. They could be carried through without substantial disruption to scientific and technical staff. It will take considerable leadership to carry through such changes because the science system has created a whole new industry of dependents and interest groups. Once any new fund has been created, a constituency of administrators, science providers and others builds up around it and it is very difficult to redirect funds to higher value uses.

Implementing the above proposals would give confidence that we have an effective policy framework for publicly-funded science in New Zealand and that it is worth investing in, not only at current, but potentially much higher, levels. The case for a substantial and sustainable increase in public research investment rests on its potentially high social returns, the human capital spin-offs, widespread market failure in industry research, the contribution public research makes to global connectedness and, above all, the contribution to New Zealand's transformation into a more diversified, technology-based economy that can lift us to a higher per capita income growth path.

Time for a new agenda: Maximising the nation's scarce resources

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Nostalgia is not what it used to be

As one brought up in the social sciences, I look to history, systems and processes (i.e. people-based things) in order to make sense of the social and political environment. So, in this essay, I will rove over interpretations of our recent past which, in my view, shape – positively or negatively – our development as a performance-based science community.

I will then turn to some policy and process concerns and proposals. These are dealt with more fully in the ACRI paper, *Transforming New Zealand through Science: core concepts for a performance based science system*, August 2002 (www.acri.cri.nz/views/statements.html).

Let's get the discussion about the past out of the way first. Then we can move onto the key issue: how to maximise our scarce resources so as to produce enduring benefit to this nation from our science and technology.

That is the single most important policy – and practical – matter in front of the private and public sector science enterprises today.

The past, however, is important for two reasons. The many hard-headed policy options being presented from some quarters arise from particular views of the past, and are often unchallenged or even acknowledged as particular world views.

First, the past established our current systems and institutions. It is important that we understand what happened and why, so that we might learn and apply the lessons

Second, some interpretations of the past constrain our future. Constant, often sterile, arguments about interpretation sap the energy needed to create future value from what we have today. It is diverting, in all senses of the term, to chase wild geese.

One interpretation of the past is that there was a Big Bang – usually cited as the transformation of the DSIR and other State-owned research areas into ten CRIs in 1992. An inefficient science system was brought into the 20th century, only to stagnate immediately. This view sustains those wanting to renew the revolution. For them, the tea break has been far too long!

For others, the pervasive tone is regret, even anger, at the loss of the golden pre-reform era. In this view, the structures, research priorities and relationships with end users were about right back then, and whatever problems there were could have been solved simply with more funding (not, note, investment).

In this view, New Zealand's world-beating primary production sectors provided irrefutable proof that the system was producing science of relevance and excellence. The aim was to do better tomorrow what was being done today. The 'reforms' are characterised as jettisoning New Zealand's natural strengths in science and traditional production sectors in favour of the global fashion of the day.

The first view misleads by ignoring the substantial change beginning in 1987 and continuing today. Even if the entities retain the same name, their practice has changed, usually for the better. The second view takes its holders further away from influence, reinforces the sense of marginalisation and does nothing to build bridges to those who are indeed captured by the current 'growth' fashion. More importantly, it undermines those who wish to build on (not replace) the traditional strengths of our nation.

Both world views also fall into the trap of all autobiography: placing themselves centre stage. Yet it was not really until the 2002 general election that science policy in New Zealand became national and public, and even then, it was really only a particular application (much as the Clyde Dam was, a generation earlier).

Science reforms as autobiography overstate the importance of science as seen by others. For example, what was the public notice of critical science-relevant legislation in 1987, 1990, 1992, 1996, 1997, and 2001?

Even now, we have nothing to rival Harold Wilson's 1964 election winning appeal, for Britain to build on the white-hot heat of technology.

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The New Zealand science system was merely another item on a reforming agenda applied to all and sundry, including core State functions (e.g. Justice, Social Welfare). Criticisms were offered to justify change, not to initiate it, and science lacked the support (or the unity of purpose) to withstand them.

There is a clear policy implication for today: has science (and its contribution to innovation and value creation) won any greater role in the national political economy? If not, when the global economy is routinely accepted as based on knowledge, why not?

Science enterprises stand the same risk as in the 1980s – being struck quite indiscriminately by the reverse swing of the blunt pendulum of policy fashion. There will have been no gain for the pain, and once more science will assume the role of provider, rather than partner, in the nation's social and economic development.

At present, science enterprise is neither a core nor a universally respected participant in the dialogue between the public and the politicians. Scientists are, at best, seen as providers of specialist, contestable, information; at worst, as self-interested to the point where anyone called a 'concerned scientist' automatically indicates one opposed to some (new to the public) scientific method. Those getting on with it are never, it seems, 'concerned' about their society.

This is a substantial and urgent challenge to all in science leadership, and will need to be addressed in ways significantly different from the present.

Assuming that a better-informed public will love science more is to chase a demonstrable failure. As the British and European experience of the last 20 years and successive Eurobarometers attest, the more scientifically literate a country, the less trusting its citizens are of science.

The third way?

The choice of world views is not between revolution and reversion. There is a third way, founded on defining the core concepts for a performance-based science system. It is challenging because it asks all entities to step aside from patch protection.

It is also aspirational: asking people to consider what is possible and desirable, rather than become immersed in bitter recollection of what has gone before in a system predicated on self-serving silos.

Fortunately, we have a 'new, improved' base upon which to build. A little-noticed change has been the arrival of a new breed of leadership amongst the science enterprises: science-literate, if not always scientists; business savvy, often coming from innovation-based companies and with overseas marketing experience; a background in industries dependent upon science and technology; valuing the creation of new knowledge, and fervent in applying such knowledge to meet economic, environmental and social needs.

This generational change, while a natural consequence of organisational maturity, is profound in its effect. The first one or two sets of leadership had the hard task of ensuring the viability, not to say credibility, of their enterprises (at policy, purchaser or provider level); developing a unified culture from diverse entities; creating niches and new relationships in the science and industry marketplace; and learning how to combine public good and commercial imperatives with science of excellence, relevance and challenge.

The new leadership benefits from that success. With their background, they also see where things might now be done differently. In particular, they have the determination to work towards a healthier, constructive, and more responsive and outward-focused innovation system.

Some entities are slower to change than others. The CRIs have advanced because they have been through the fire of competition, and seen the charnel house it can make of nationally valued capability. The research associations are seeing some of the same. The universities are entering the fire of performance-based research funding and the other incipient reforms of the Tertiary Education Commission.

As Change Management 101 teaches, the first requisite for change is to 'unfreeze' the existing. This is happening, slowly and painfully.

But let's celebrate the advances that have occurred, be it at the easier bi-lateral, entity-to-entity level, or the national system level. For example, the idea of Centres of Research Excellence is ripe with the possibility of enabling New Zealand's scarce science research resources to reach new heights, and will surely mature to achieve this. At present, the best examples are driven by personal relationships rather than through embedded processes.

Closer relationships do not mean undue overlap, as CRIs and universities should demonstrate in their complementary roles. It is important that people coming into commercialising science enterprises understand the environment and have the necessary set of skills. The cross-linkages are vital to nurturing new, as well as existing, scientists (CRIs mentor, supervise or train some 500 graduate and post-graduate students per annum).

The greater clarity of purpose that CRIs now have, courtesy of the annual Operating Frameworks, is also emerging around universities. The Frameworks (see www.ccmau.govt.nz) clearly define the public-good purpose of the ownership by government of CRIs and the commercialising role of CRIs within the Growth and Innovation Framework.

CRIs are catalysts in the economic transformation of New Zealand, providing leadership and push, as well as responding to market pull.

The challenge is still huge, as can be illustrated by a telling paragraph from the Landcare Research Annual Report 2002 (page 7):

> *During the disastrous five years before CRIs were formed, New Zealand lost 27 per cent of its science capability in our research areas and science salaries suffered a 15 per cent reduction in real value. We have now restored science staff numbers nearly to 1987 levels, and fully restored the real value of science salaries.*

How does one attract the best and brightest, when our story is that we have sweated blood to ensure that salaries match that paid to their parents 16 years ago?

A new approach needed

A key moment in the growing maturity of the science enterprises was a workshop held in February 2003. For the first time ever, the chief executives of the CRIs and the research associations, and the university deputy vice-chancellors (research) met with each other without the presence of 'mother MoRST' or 'father FRST'.

Agreement was reached to progress three key issues – seamless collaboration between the entities, early stage funding for commercialisation, and identification of platforms of national significance. Work will begin on the latter issue this winter.

Recent moves to re-integrate policy and operational departments do not overturn the Principal-agent theory approach of the 1980s to 90s, but it does indicate that some blurring of lines is politically possible. The rigorous quarantining of purchaser, provider and policy agents created barriers to exchange and learning, and led to loss of capability and capacity.

Today, cooperation, collaboration and co-optition are recognised as key elements for best performance. These attributes maximise performance from existing resources and encourage development of future competency, capability and capacity.

Concerns with the present system

The science enterprises workshop was developed on the basis that any system needs regular re-alignment of its purposes and practices against core principles. The number and strength of concerns expressed by a range of entities in the national innovation system suggest that the time is right for well-planned, evolutionary change. Narrow operational concerns may lessen, or even disappear altogether, if there is a well-defined, integrated system with clarity of purpose and expectation.

Specific areas of concern include system issues (such as stability of the science system, barriers to performance, roles and responsibilities of individual entities within the national innovation system, excessive compliance costs, quality assurance), human resource issues (e.g. certainty of career paths and research programmes, retention and development of human capability within New Zealand), funding issues (e.g. sources and allocation of funding, misalignment of accountability and control requirements).

Future direction issues include the strategic direction of the system and indications of system failure; alignment of strategy of the Crown-owned policy advisers, purchasers and providers, and of the wider system components; commitment to long-run science research; means by which to encourage effective collaboration amongst research providers; and retention of critical mass within New Zealand.

Concepts for a performance-based science system

Some 13 core concepts are identified. The first set is grouped under principles, purpose, vision and objectives for the national innovation system, while the remainder come under strategies, structures and process. In the first set are clarity of purpose and expectations, seeing value as economic, social or environmental; a commitment to serving the national interest and the long term. In the second are the need to identify and nurture the capabilities and competencies required for today and for tomorrow; to differentiate between funding and investment; to balance dynamism and stability; to match accountability with control; to use scenario planning to provide a robust basis for strategic direction; to encourage and reward collaboration and reduce duplication; to enable contestability, including through new entrants; and to create portfolios of long-term value-creation programmes.

Transforming New Zealand

These matters must move beyond words. The CRIs have already begun modelling amongst themselves the difficult task of making this work, knowing that it requires trust and goodwill as much as formal alignment. It must not be an imposed, top-down directive.

By doing this, and by working with others, CRIs assert the need for the insight, experience and learning of those most closely connected to industry, science and global knowledge, in order to influence national priorities as partners in the process.

Benefiting New Zealand in a global market

Science, especially excellent science, requires competencies and capabilities (physical and human) that are not bounded by the borders of any nation-state. New Zealand has to acquire, develop, maintain and share skills, knowledge and networks on a global basis.

We can then apply them to solving problems which are unique to New Zealand (and which others will have little or no interest in solving); and benefiting New Zealand's economy, society and environment.

This requires New Zealand to:

- build capability based on existing areas of knowledge and excellence,
- define and occupy niches based on those areas, and
- exploit those niches intelligently.

Retention and development of good people are critical, not only to service existing needs, but to enable New Zealand to meet tomorrow's. The global talent wars have already begun, yet the national stewardship of the nation's capabilities remains fragmented through existing purchase arrangements. New models, with purchaser and provider as allies, are required.

Conclusion

New Zealand must be smart about what it needs; what it wants; how it allocates its resources (for what purpose and to whom) and the process by which this allocation is handled.

It is unlikely that the present system needs radical change. While there will be different conceptions of just what constitutes 'national good', we can at least agree on the core concepts and then get on with the task.

If we do not, we will relegate ourselves to the margins of the society we seek to serve and will fail to deliver the economic, environmental or social wealth that New Zealand deserves.

Enhancing the performance of the RS&T system

Nick Allison
Foundation for Research, Science and Technology

Introduction

How can we lift the performance of the research, science and technology (RS&T) system to increase its contributions to the wealth and wellbeing of New Zealanders? RS&T has contributed to New Zealand's success, both by adding value to existing industries and by developing new industries. To achieve Government's objective of improving New Zealand's OECD ranking, RS&T will need to make even larger contributions to lift our sustainable growth rate.

The RS&T system includes RS&T activity in the private or public sectors, and improving the management of this system is the focus of this paper. My contention is that its performance could be lifted through changes in, and improved clarity of, roles, responsibilities and accountabilities. When decisions are made in the wrong places within the RS&T system, there is likely to be an associated failure to execute actions. Decisions need to be made by those closest to the information and who have the incentives to perform. This requires an understanding of the competencies and comparative strengths of key players in the system. It's about all of us doing what we do best, thereby jointly lifting the overall performance.

Doing what we do best

First, it is worth outlining the Foundation's role within the RS&T system. The Foundation is Government's principal RS&T Purchase Agent investing:

- nearly $400 million per annum, including $12 million in fellowships and scholarships,
- across the research spectrum from basic research and on into development,
- in most sectors, including the environmental, social and economic arenas, and
- with an extensive client base, involving over 1300 contracts.

At over $270 million pa, Crown Research Institutes (CRIs) are our largest clients by value. We also invest over $70 million with the private sector and around $44 million with universities.

It is important that we understand what we can do well and what is best left to others to do. For the Foundation, this means leveraging our unique position in the RS&T system to build competencies that enable us to invest funds for the greatest benefit for New Zealand. Our role and extensive client relationships enable us to build an extensive knowledge base concerning:

- the nature of the country's RS&T investments, including emerging research directions, and
- the performance of these investments.

These *core* competencies support our ability to develop strategic research directions, run investment processes of integrity, provide performance incentives for research providers and advise Government on investment priorities.

The changing face of the RS&T system

In the late 1980s Government's role shifted to purchasing research from which *no single individual could capture the benefits* (pure public good). Concurrently the DSIR was split into commercially oriented CRIs. These changes were intended to strengthen contributions to strategic sectors of the economy, while having the private sector pay its way (which previously had often been given the products of research at no cost).

To make matters challenging for CRIs, competition increased when universities entered the Public Good Science Fund. In addition, for most of the 90s, the Foundation's pure public good mandate did not sit well with CRIs' commercial objectives. Further, the architects of the new structure forgot that science knows no boundaries. While CRIs were aligned with sectors, science works in ever-changing disciplines. Today, the CRIs find that they need to transform their businesses to take advantage of opportunities arising from RS&T capabilities that are led by markets outside their own sectors.

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The Foundation has collected extensive RS&T performance data and, given RS&T investment time lags, these data reflects on the effectiveness of *past* changes and policy settings. Our data reveal that:

- numbers of internationally peer reviewed papers have increased in recent years and are high relative to OECD averages ,
- international collaborations have grown, and are at least as strong as domestic collaborations,
- strategic partnerships between research providers remain modest,
- engagement with research users is typically poor to modest, and is reflected in low levels of user co-investment,
- public sector science providers produce a relatively small output of codified intellectual property (IP).

Without more extensive evaluation work it is difficult to draw firm conclusions on wealth and wellbeing outcomes. However, several of the above indicators suggest that there may not have been large spill-over benefits for the economy from government's RS&T investment.

Changes to the system

Over the last five years we have again been going through a period of substantial change, including the following:

- The Foundation using national benefit investment criteria which encapsulate a wider role for Government than provision of *pure* public good science.
- Public providers being given a stronger mandate to take RS&T to the market.
- The establishment of the Preseed and Venture Investment Funds to support commercialisation of RS&T.
- The rapid growth of basic research through the New Economy Research and Marsden funds.
- Growth of RS&T support for firms, with TechNZ funds more than doubling in five years.
- The Foundation opening the 'contestable' public-good funds to a wider spectrum of players, partly through decoupling bids from team 'audit funding trails'.
- A rapidly growing investment in Research Consortia partnerships, which to-date has seen the Foundation commit some $50 m and private parties a further $60 m over a five-year period.
- The Foundation making more extensive use of long-term contracts and shifting to a continuous rolling portfolio investment process spanning more than five years for each investment cycle.

These changes are creating greater dynamism in the RS&T system. They have facilitated funding shifts to meet Government priorities, provided for entry of new teams and new ideas, and built new relationships and networks. The first signs of success of these changes include a rapidly increasing quantity of codified IP from public sector providers, and strengthening user-provider engagement.

Individual researchers and CRIs alike have raised concerns over the uncertainty inherent in the changes. These concerns should not be dismissed lightly. They occur in the context of low salaries for scientists relative to similar professional groups, and a perception of a lack of career development opportunities, reflected in student subject choices. Unless these barometers show improvements, the above changes will fail to lift the performance of the RS&T system. Performance depends on having highly skilled and motivated and people.

Rising to the Minister's *i*^{3} challenges

The Minister of RS&T has raised three challenges for the RS&T sector concerning the need to:

1. Set clear RS&T directions or priorities [*ideas*]
2. Strengthen RS&T capabilities to support *innovation*
3. Extract greater commercial value from our *investment* in RS&T.

These are all areas where we can improve performance. The changes described above provide a supportive environment to extract greater commercial value. It is now up to science providers to develop the culture, skills and market relationships to take advantage of this environment. There is no reason to doubt that they can rise to the occasion. Success will lift demand for RS&T and consequently improve job prospects, security and salary conditions for scientists. Of concern is our performance in setting long-term research directions and managing associated capabilities.

Setting RS&T directions

As we again move to clarify research directions, it is important to learn from our past experience. It's worth asking two questions: who *owned,* and who was *accountable,* for achieving Foresight strategies? The short answer is: no organisation, nor partnership between organisations, owned the strategies and, accordingly, no-one was accountable. The final product was an amalgam of good ideas, crafted by many hands, but owned by no-one. And therein lies the problem!

Learning from the past

An aim of the 1998/99 Foresight Project was to "refocus public investment in RS&T on outcomes that will contribute to New Zealand development as a knowledge society." However, this aim was not achieved, either in strategy formulation or in implementation.

Target Outcomes such as 'Healthy, Diverse and Resilient Ecosystems' are but platitudes that do not provide benchmarks for forming priorities. The Foundation folded 120 Foresight Strategies developed by sector groups into 25 Strategic Portfolio Outlines, disassociating end-user groups from the final product. Foresight directions were then diluted through the use of 72 portfolios through which the Foundation invested funds.

Failure to form and to execute strategy well is endemic in the public sector. Anyone who has worked in the sector in recent years is aware of the piles of strategies formed on strategies. Some will argue that this is due to 'salami-sliced' government structures. While structures do matter, it is ultimately an issue of leadership and clarity of roles and responsibilities. This is particularly so where activities cross organisation boundaries, such as priority setting processes between MoRST and Purchase Agents.

The 1980s public choice model established Purchase Agents such as the Foundation. By definition, a Purchase Agent is handed a *purchase order* and goes forth to procure. This is fine if you're a broker of shares, but it's not so easy in the public-good science business. Embedded in an executable strategy is substantial *tacit knowledge and relationships* that do not easily form part of a purchase order. In reality, the Foresight Project purchase order was too large and indistinct to digest. The model's architects overlooked the difficulty of the *principal* acquiring sufficient knowledge to form a purchase order and convey this tacit contract to the agent.

The past STEP and SPiR priority-setting processes led by MoRST also failed to produce significant changes in direction. Because of the highly aggregated information inputs to these large one-off processes, prudent decision-makers need to be risk-averse in forming priorities that affect the careers of thousands of scientists. Thus, while large one-off processes risk swings in priorities, they are more likely to produce results too indistinct to form part of a purchase order.

An implicit assumption in these large priority-setting processes is that Government priorities are all set once every five years. They are not. We need a *continuous incremental process* of setting and revising RS&T directions, which can adapt and adjust to changing opportunities and future outlooks. Purchase Agents, who run investment processes and have the comparative information advantages, are best placed to manage continuous priority-setting processes within policy parameters set by government.

MoRST's role

MoRST is Government's principal adviser on RS&T policy. This role is broader than the RS&T system and MoRST can also develop and contest advice to Government on the wider innovation environment. It is also responsible for overseeing international science treaties and monitoring the performance of RS&T Purchase Agents.

MoRST was established in part to manage the process of setting RS&T priorities. STEP and SPiR (Science Priorities Review) focused on assigning dollars to priorities, which were then communicated in a 'Statement of Priorities' to purchase agents. Foresight took more of a systems approach, assigning responsibility for purchasing balanced portfolios to Purchase Agents. This implies that Purchase Agents develop priority-setting processes. MoRST's role is likely to evolve to advising the Minister on the *parameters governing* RS&T priority-setting processes and monitoring the performance of these processes.

Policy parameters would include broad *national* priorities set by the Government, such as the focus on the biotechnology and ICT sectors. Parameters could also include a view of the expected rate of change anticipated in achieving the priorities. However, it is ultimately up to Purchase Agents to allocate resources according to these and other changing priorities, and for the results of which they should be held accountable. To give effect to this kind of system we need a new form of a 'Statement of Priorities', which communicates expectations of parameters for which purchase agents are accountable.

The Foundation's role

The Foundation is building a continuous incremental priority process. This has begun through establishing longer-term contracts and a continuous investment cycle. Performance evaluation is used to support staged portfolio reviews, setting research priorities, and for advice to the Minister on broader research directions. The Foundation is taking on this priority-setting role more actively, and recognises that the *information advantage* to set and assign resources to national priorities lies with the purchaser.

Of course, this process needs to involve the RS&T community, at the very least to help set achievable stretch objectives. Indeed, the Foundation Act requires us to consult with the wider public in priorities.

Investment in, and management of, national capabilities

When we ask providers what they consider to be capabilities of national importance, some tell us that *all of their work* builds these capabilities. This may be an unfair question, as providers do not have the national perspective available to a dominant purchaser. However, the answer illustrates the problem of establishing these capabilities through a bottom-up process. Equally, one can argue that leaving this task to a central purchaser is akin to putting all of one's eggs in a single basket.

There is no agreed definition of RS&T capabilities of national importance. Getting agreement is central to defining who is responsible for these capabilities. We have been advised that capabilities include everything from semen research to expertise on bugs that might one-day invade New Zealand. However, these are RS&T *competencies*, taking the form of skilled individuals and teams who excel in their chosen areas. A capability is a combination of competencies and resources that together can produce a tangible output. *National RS&T capabilities* take three forms:

1. Knowledge infrastructure – collections and databases that embody decades of research and underpin many areas of ongoing research effort
2. Response to national risks – research capabilities able to address significant national risks, such as biosecurity threats
3. Creating future opportunities – research and technology platforms that give us the ability to create new futures, including adding value to existing industries, building new industries and responding to changes in broad national directions.

The Foundation's role

The first two capabilities listed above are here with us for the very long haul and need to be managed on that basis. It is sensible for Government to take a national or top-down perspective to ensure that capabilities remain adequate; that there is no redundancy and that they are well coordinated. This does not translate into a standing army of experts on bugs. However, it may translate into centres of expertise, spanning research providers, working on prevention and management of pests, with clear tangible objectives agreed with the purchaser. Setting clear directions and facilitating coordinated management largely addresses the question of capabilities implicit in the first two areas listed above. This would also enable the Foundation to invest through negotiated long-term performance-based contracts, consistent with sustaining these capabilities.

The role of providers

The last set of capabilities (creating future opportunities) should not be left to the purchaser, or to any provider alone. Investing in RS&T platforms is akin to taking a bet on the future, and at times the competition of ideas for this future among providers is fierce. However, no-one has a monopoly on what shape the future will or should take. The Foundation will never gleam the RS&T expertise, market knowledge and relationships to develop strategy to make specific bets. Rather, the Foundation needs to set clear but high-level objectives, such as increasing the value of RS&T-based exports, use effective proposal selection criteria, and then select the winners that emerge from largely bottom-up processes.

As investment shifts to the winners, it is important that providers manage changing capabilities. Some providers have told us that not supporting particular projects will result in immediate redundancies. However, research contracts exist between the purchaser and the research organisation - not the research team. A key role of management is to ensure that exposure to risk does not fall unfairly on the shoulders of a few. Otherwise, what value does management add for the researcher? Teams might as well contract directly with the Foundation. Indeed, the old audit-funding trail was a de facto form of such a contract, and some researchers may have seen the Foundation as their employer. This era has passed and providers now have to manage their exposure to risk, although the Foundation does assist with making difficult transitions that result from changes in its investment.

This raises a conflict inherent in addressing the first two of the Minister's issues. In a changing global environment national priorities will change and, along with these changes, so capabilities must change also, perhaps many times over the life of a scientist. There is no instant nirvana of stability for scientists if we are to invest taxpayer funds responsibly. However, there are ways in which providers can mange risk, and the Foundation can help as we move from old to new research platforms.

Helping to build the future

The Foundation has a range of initiatives that will help to *facilitate* change and build a more dynamic and performance-focused RS&T system. These initiatives include:

- The further development of tangible outcomes targets and performance measures
- A series of initiatives to act as a stronger facilitator of investment in RS&T, devolving more decisions to providers
- Development of ways to reward good performance of providers.

The development of tangible outcome targets is a central component of the continuous priority setting process referred to above. Such a process has the advantage that it signals directions, enables planning by providers and provides a basis for accountability of the Foundation. The first step involves the simplification of our complex portfolio framework so that it aligns better with Government's output objectives and is user-friendly to our clients.

We propose to extend our role as facilitator, investigating ways to devolve more decision-making, delivering where the information advantage and incentives lie, and setting appropriate performance standards. We have already made some headway in this area. For example, allowing clients to transfer contracts into consortia where sufficient co-funding is attracted and science quality is maintained, thereby avoiding the contestable proposal process. A further initiative involves implementing a contract monitoring system that enables us to reward performance through contract renewal. These mechanisms not only give teams greater control over their own destiny, but will also provide incentives to perform and reward performance.

However, while the Foundation can help to set the framework within which the RS&T system works, it is ultimately up to the RS&T organisations themselves to succeed.

The policy prescriptions

In summary, the I^3 Challenges concerning setting national directions and strengthening national capabilities, could be addressed with the following policy prescriptions:

1. MoRST is made responsible for advising the Minister on the *parameters governing* priority setting processes run by Purchase Agents, and monitoring agent performance. The parameters would form the basis of performance contracts between agents and the Minister.
2. Purchase Agents operate incremental and continuous priority setting processes in accordance with these parameters, which would include national priorities set by Government.
3. Parameters would include expectations relating to the management of national capabilities concerning science infrastructure and management of national risks.
4. Purchase Agents design investment processes to devolve decision-making to providers where there are appropriate incentives to perform and adequate measures for accountability.

Many aspects of this system are taking shape. As noted before, they were implicit in Foresight and, indeed, the Foundation's Statement of Intent contains a set of operating principles akin to the *first* edition of the required parameters. We now need a wider understanding of these emerging roles and clarification of the associated responsibilities in accountability documents.

Environmental research and science policy

Janet M. Grieve
NZAS Council

This article represents a personal view that does not necessarily reflect the view of the organisation I work for.

Introduction

Since the science reforms of the late 1980s and early 1990s, the full operation of the contestable allocation of research funding in 1991/92 (MoRST 1995a), and the creation of the Crown Research Institutes in 1992, the science system has undergone many policy and operational changes. These changes include adjustments to the mechanisms for the purchase of research that have been accompanied by a reduction in transparency. The changes were made in a setting where the role of environmental scientific research as a contributor to the implementation of Government's environmental policy has become unclear. Unfortunately, many scientists have become disenfranchised in the policy formulation process.

Changes in the science system

The original system was set up to include a rolling, 3- to 4-year priority setting exercise that involved wide consultation, that took into account the needs of government departments, and that was relatively transparent. Two such exercises took place in 1992 and 1995, resulting in reports (MoRST 1992, 1995b) that discussed various funding scenarios and suggested changes to the allocation of resources between different research areas. Government departments, local authorities and environmental NGOs (users of environmental research results for the public good) were able to contribute directly to the priority setting process. In conjunction with budget rounds that assigned the total Government expenditure for science and technology, the Foundation for Research, Science and Technology commissioned Output Strategy statements (drafted in consultation with scientists) that indicated the priorities in each Output area. These documents then fed into the annual competitive funding rounds. Thus, the scientists involved in each area of science, not only had the possibility of providing input into priority setting, but gained a clear understanding of the rationales and motives underpinning priorities at all levels. Institutions were also able to plan ahead, having been given plenty of warning about future changes in priorities.

All this took place in a political climate in which established principles allowed scientists to predict what science would be supported and what would not. One of these principles was that Government should invest in 'public good' science that no one sector could pay for. Research on the natural environment is a quintessential example of public good research.

The priority setting process, and its outcomes, nevertheless frustrated many bureaucrats, and science managers. They perceived that a few strong personalities could exercise undue influence on the outcomes of priority setting. Additionally, it was clear that some politicians were susceptible to lobbying from interest groups and would not accept certain priority recommendations (see Science Priorities Review Panel 1995 recommendations by comparison with what actually happened), and that the inertia of existing funding levels made it difficult to change priorities substantially.

Nevertheless, this group of bureaucrats and science managers exerted much influence and were able to make changes to the priority setting process in what is now perceived to be a very ad hoc manner. In doing so they engaged politicians directly as politicians were perceived as an impediment to progress when kept at arm's length. They also seem to have repealed the notion of 'public good' as the chief criterion as to which research areas Government should fund.

The Foresight Process

The vehicle of change, begun in July 2000, was the Foresight Process. This process aimed to identify opportunities for New Zealand and its economy. There was probably nothing wrong with the Foresight methodology, but there was no open, transparent, subsequent priority setting process. Instead, the New Economy Research Fund was created partly by transferring money from what is now the Public Good Science and

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Technology Fund (previously the Public Good Science Fund), and the Marsden Fund received additional resources for basic research. The emphasis was apparently to get 'NZ Inc.' to invest more in research and initiate more Government and private partnerships, research consortia etc. Government was encouraged (forced?) to make decisions at a relatively low level concerning research preferences. There was much debate about increasing the proportion of Government spending on research aimed at the economy and secondary production, while decreasing support of research underpinning the primary production sector and, by inference, the environment.

In retrospect, it is now very difficult to track historic changes in priorities and allocations in environmental research because the FRST web-site currently presents data only for the periods 1995–1999 and 2002/03, and because of changes to research classifications made in 1999/2000 (and on prior occasions). For example, the change to the definition of environmental science, to include energy research and research aimed at mitigating environmental damage caused by particular sectors of the economy, has obscured what has actually happened to funding in that sector. Because of this change, core environmental research is now grossly under-resourced, although total environmental research appears superficially to be funded as well as ever. Because these strategies are not transparent, there has been little evaluation of their implications for other areas of Government's investment interest.

Environmental research and science policy

Environmental research, particularly that not immediately related to climate change, has come off rather poorly, in spite of the fact that some of it falls within the Government's priority areas (e.g. research related to Oceans Policy). This has occurred because these areas were last in the queue for 'advancement'. What has actually happened, and why, has not been clearly documented, and so the science community is forced to second guess the policy changes that underpin decision-making on environmental research.

How did such a state of affairs come about? Has this been a deliberate strategy or is it an accident of poor planning resulting from the *ad hoc* nature of management of the sector in the recent past? Is there a Government policy for informing environmental policy and its implementation through the application of environmental science? We feel obliged to ask this question because in most high level documents and papers from the Ministry of Research, Science and Technology and the Foundation for Research, Science and Technology, environmental science is rarely mentioned, and then without clear recognition of the distinctive nature and objectives of environmental research, nor its special relationship with end-users.

For example, the *i*³ Challenge pamphlet (Minister of Research, Science & Technology, 2003), that announces the strategic direction for 2003–2005, makes token mention of the environment, but contains no articulation or development of the role that environmental research plays in implementing Government policy. Instead, the pamphlet is almost entirely devoted to discussing the economy. For this reason, and because very few scientists are engaged in policy formulation, priority setting or implementation, and because resources with which researchers make their contribution have been considerably eroded by inflation, environmental researchers feel that there is little support for their work.

The lack of a clear environmental research policy is underscored by an apparent mismatch between what has actually happened to the support for certain areas of Government environmental research and Government's policy objectives. For example, Government is currently formulating its Oceans Policy (Ministry for the Environment, 2003). In the relevant working documents, there is mention of the need to plan, prioritise and resource the generation of information required for a range of marine management functions. This implies that a clear environmental policy does not currently exist for ocean research (and probably doesn't exist for terrestrial research either). This lack of over-arching policy, in addition to ad hoc purchasing, has resulted in, for example, the transfer of parts of a FRST-funded marine ecosystem functioning programme to climate change programmes. FRST moved certain objectives out of their original, carefully planned programme, and reduced resources that underpinned scientists' ability to give advice on aquaculture issues, carrying capacity and allocation of space and resources in the coastal zone. That is, current processes do not allow a considered debate that weighs up the relative priorities of underpinning research that supports oceans policy development, compared with research supporting climate change.

Marine biodiversity is another priority research area. Yet one FRST-funded programme that contributes directly to our knowledge of New Zealand's marine fauna and flora has had no compensation for inflation since 1995/96 (Fig. 1). This programme (and others treated similarly) will have suffered up to a 22% decrease in real purchasing power, and a commensurate decrease in ability to contribute if no substantial new money is allocated before 2005-2006. A further delay in 'advancement' and consequent extended freezing of research funding for marine biodiversity and related programmes has been announced recently. Environmental scientists are extremely confused by this apparent mismatch between Government's words and actions.

Recommendations

Those working in the environmental sector would like to see a reasoned debate, longer-term policies, budgets, and plans relating to the environmental sector, that recognise the nature of the contributions made. In particular, there must be clear recognition of the diverse range of end-users in this sector. Local and central governments are the main end-users with an interest in the needs of current and future generations. By comparison, private sector end-users sometimes adopt a short-term view that conflicts with the needs of future generations, especially where regulation of particular activities is concerned. Therefore, effective institutional arrangements to purchase research must be devised, and procedures put in place that do not give undue status to those with conflicts of interest. Environmental scientists must engage directly in policy formulation and implementation, as it is they who have the deep technical knowledge of what is known and what it may be possible to learn. Short-term secondments to the relevant departments would be a good way to engage their expertise.

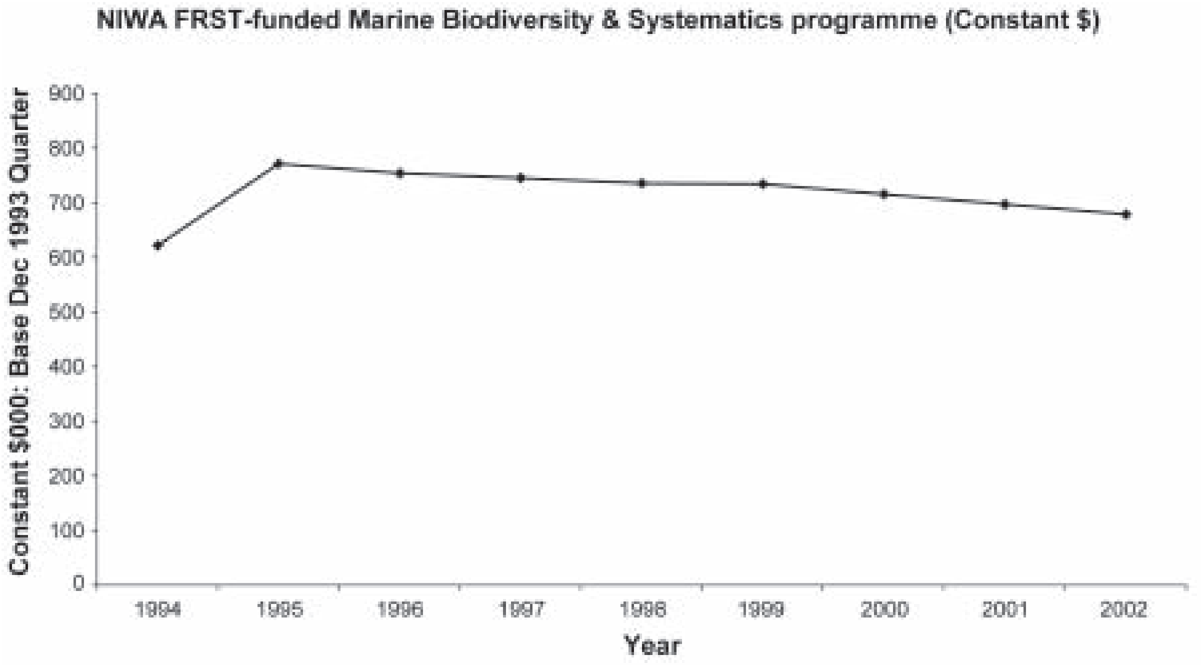

Figure 1. National Institute of Water and Atmospheric Research FRST-funded marine biodiversity and biosystematics research programme (exclusive of GST) in constant December quarter 1993 dollars from 1994 to 2003. By the time this programme is 'advanced' it will have lost 22% of its purchasing power, assuming the same rate of inflation.

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Development of science discoveries in the New Zealand Crown Research Institutes

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Introduction

This paper focuses on the Crown Research Institute contribution to New Zealand R&D. CRIs carry out the bulk of government funded (PGSF) R&D and it is our expectation that R&D strategies are based on existing or new areas where New Zealand could develop an enduring competitive advantage. An example could be current unmet market needs for sophisticated human protein therapeutics where New Zealand is at the forefront of cow transgenesis, seen increasingly as an attractive means of production, in a country free of BSE and scrapie. The paper also assumes (and develops) the following model (Figure 1) as a discussion base in the logical progression of a concept through the innovation spectrum[1].

Discovery and development costs

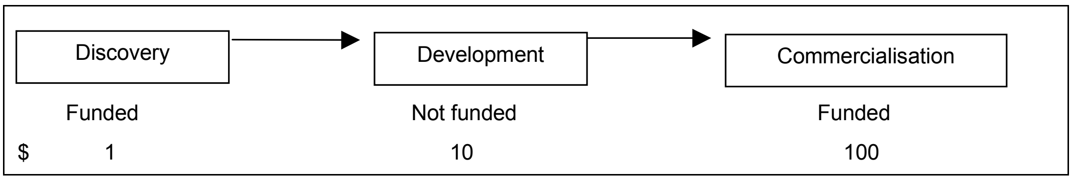
For sake of clarity in the ensuing arguments we hold that the quantum of public good science funding (PGSF) in New Zealand is not excessive by OECD norms and is in fact low by these standards[2,3] and distributed approximately correctly i.e. 50% basic research[4], 30% applied research and 20% experimental development[5]. We also assume that there is a need to produce approximately ten to twenty discoveries in order to select one attractive one to take through development.[6,7] The critical part of the spectrum in this, as in any other research strategy, is the '*development*' link. Figure 1 is a model of funding realities in the New Zealand situation and an estimate of ratios of costs in each segment of the spectrum[1].

This paper assumes that if '*discovery*' and '*commercialisation*' take place, they are funded. '*Development*' in general is the poor relation and is not funded because it has no obvious saleable value. The challenge for New Zealand R&D and research organisations in general is to find development funding that will not distort activities on either side of it in the spectrum shown. If this is adopted as a driving principle i.e. supporting *development* without draining *discovery* or misleading *commercialisation,* then New Zealand must invest in R&D appropriately and balance the spectrum correctly. Obtaining the right investment in the spectrum parts must somehow be coordinated across the public and private sector funding mechanisms.

Discovery, development funding and lead times

In 2002/2003 New Zealand invested $403.5M in 'PGSF' through the Foundation for Research Science and Technology (FRST)[5] CRIs derive major income from FRST, and under the CRI Act are required to operate as a viable business and to

Figure 1. The innovation spectrum, with estimates of the ratio of costs.



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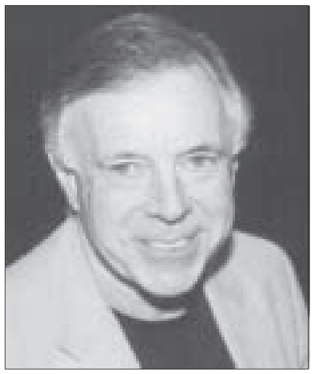

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benefit New Zealand through science infrastructure and research output. Nothing in the Act specifically requires CRIs to fund development though it is often assumed that PGSF will provide for that when in fact it does not and cannot, given the dollar logistics[1] evident in the above model. The problem is that *development* funding is nonetheless expected of CRIs by government and, unfortunately, the private sector. This expectation poses a number of problems for New Zealand science, not the least of which is exactly that this expectation may withdraw funding from *discovery* running down the science infrastructure. This statement takes on more significance when analysis of agricultural research investment shows returns averaging 50% i.e. that the research is undervalued or in economic terms under-invested [7, 8, 9] reinforcing the assumption above that the PGSF spend in primary production R&D at least may be under-invested in *discovery* and cannot be regarded as an opportunity for resourcing *development* in the amounts required to do so successfully.

If diversion from *discovery* to *development* does occur it may well be misspent as the PGSF dollar allocation is not enough to fund development to useful outcome and discovery half-developed from a commercial viewpoint is almost as useless as something not developed. In addition, 'Mother Hubbard's Cupboard' will run to empty as the *discovery* capital stored there by previous government policy is used up in the relatively long lead times between *discovery* and commercial result in biology. An example might be Androvax, a widely used successful sheep fecundity (twinning) vaccine sold by AgVax Developments Ltd that is credited in part with New Zealand's phenomenal increase in lambing percentages in the last decade. The active component, androstene dione, reached proof of concept in 1976, commenced development in New Zealand in 1979 and its first commercial sales in 1993. This is not unusual and lead time to useful commercial outcome from *discovery* is around 9-10 years in traditional drugs or 12-15 years in biology based discovery [10,11].

There is a very similar story for Toxovax, a sheep abortion preventative vaccine which also can be credited with improved lambing percentages. Given this lead time reality and that if '*discovery*' resources have become limiting, it can be predicted that about 15 years after the establishment and operation of CRIs (i.e. 2007–10) on the current policy land-based CRIs at least will find themselves bereft of significant positions in attractive new discovery[12] worthy of development and increasingly non-competitive in the scientific world-stage. There is evidence of this happening in Table 1 as more and more of the scientific 'output' is not in the internationally published category.

CRI record of internationally competitive science

Table 1, which is a compilation of publication data collected from annual reports of the CRIs over 10 years, illustrates the point that international publication rates are relatively static in most CRIs. In analysing these data we do not treat CRIs differently, and we make reference to 'Key Non-financial Performance Indicators Generic to All CRIs' as set out in a policy statement by the Crown Company Monitoring Unit (CCMAU)[16] which refers to "…standard measures of output used internationally…". A variety of things are listed but the most meaningful and comparable as a benchmark relating to science discovery, and actually reported, is international journal publication. With this in mind, we note that AgResearch Ltd over ten years showed an increment in total journal publications, but the numbers of papers in international journals indicating competitive science was near static ('flat') despite large revenue increases (56%) over this time. HortResearch Ltd did not report international publications separately for most of this time but showed a precipitous decline in totals, and at best a static result for international publications in the last three years again, despite reporting significant revenue increment (24%) over the 10 years. The publication output for Industrial Research Limited (IRL) was spiky but near static in totals, again with large revenue increment (54%); likewise for the Institute of Geological and Nuclear Sciences (IGNS)[13] with revenue increment of 52% and also NIWA (127%) with a flat total of international publications in the last four years. It is clear the inflation-adjusted revenue[14] in the CRIs significantly increased whilst scientific output of international papers did not significantly increase. This is not a new analysis where publication rates of CRIs have been compared over time as a measure of research productivity[15], but we have attempted to define those in the international refereed literature and over a longer time span.

This is not a record of international accomplishment in science which might be expected of apparently healthily growing science institutions, growing as indicated by the reported revenues at the beginning and the end of the publication analysis period (Table 1). In explanation, it could be said that the reason for the flat rate of publication in international science journals is that CRI resources have been transferred into profit-making activities and, if this is correct, it is likely to be eroding the science base. It might also be that more commercially sensitive CRIs are withholding publication in lieu of patents and trade secrets. Patenting is not inconsistent with publication and should only throw in an 18 month lag before publication rates resumed at the base rate over these 10 years. If scientific productivity is disappearing into trade secrets, this would only indicate another set of problems in how to gauge New Zealand CRI science performance.

Although our paper only analyses CRIs, a contextual reality check shows AgResearch in 2001 had 593 science FTEs and published 291 papers in the international refereed journal category, i.e. a ratio of 0.49 papers/FTE. University of Auckland School of Biological Sciences listed 172 science staff (all ranks: Professors, Lecturers, Research Fellows, Technicians; no honorary appointments counted) in their Research Report and 79 papers in international refereed journals, showing a similar ratio of 0.46 papers/FTE. This comparison is useful only as a general benchmark, as it cannot account for the different duties of staff in the university and CRI environments apart from the commonality of the research functions. For example the university staff teach, but the CRIs are involved in technology transfer (a form of teaching), neither of which contributes directly to research output and possibly raises even further questions on measurement of New Zealand science R&D performance in general. Nor can this comparison account for pressures on CRIs to operate at a profit these 10 years. A useful comparison would be analysing the trends in publication categories in universities over time as we have done for CRIs and as new measures of accountability engage in the universities.

CRI reporting of science

If incremental revenue is indeed going into *development,* as one could imagine it might given the pressures on CRIs, then it may well be at the expense of basic science discovery, with the underfunding problems that implies from the model already discussed. The alternative, which cannot be distinguished from annual reports of course, is that revenue increments are going into neither science discovery nor development, but then that might only highlight deficiencies in the reporting CCMAU requires of non-financial performance indicators[16] and an apparent encouragement of and reliance by CRIs on financial indicators for their performance.

The requirement for financial viability in the CRI Act is correct, but the requirement for viability and growth without adequate countervailing science performance measures will exacerbate the problem of science underperformance forcing CRIs more and more into contract 'research' derived from another nation's science. This is clearly not the way to achieve maximum social rates[4] of return for New Zealand's R&D dollar. A healthy technology innovation company will often spend over 15% of its revenues on R&D, thus reducing earnings but emphasises the magnitude of the task being asked of CRIs in a requirement to remain internationally scientifically competitive, commercially competitive and healthy. Reinvestment in the company usually increases the value of the firm. However, its impact is neglected in the conventional P/E ratio and in the CRI model it cannot be accounted for in either of these ways – raising questions about measuring the sustainable investment behaviour of CRIs. The market, it appears, is not applicable to the CRI model when it comes to measuring science investment behaviour – raising questions as to what is. Perhaps, as noted by the eminent R&D economist Edwin Mansfield, best (social) rate of economic outcome is often associated with the best science[17] and not directly targeted [4,18] for the private sector. As the Marsden Fund experience is beginning to show, some of the best commercial ideas are coming exactly this way[17] in less targeted research which would have come as no surprise to

Table 1. Output of refereed publications by CRIs, 1993–2002.

CRI	Publ type	Revenue '93, $000	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Revenue '02, $000
AgR		84600											132224
	Intnl		281	274					249	275	291	294	
	NZ		105	112					55	160	166	264	
	Total		396	286	378	290	170	229	304	335	455	558	
Hort		46378											57560
	Intnl									121	155	107	
	NZ									61	73	82	
	Total		518	502	474	284	277	324	283	187	228	189	
IRL		37991											58654
	Intnl												
	NZ												
	Total		n.a.	150	156	145	140	144	130	384	145	374	
IGNS		25291											38364
	Intnl												
	NZ												
	Total		129	155	n.a.	171	n.a.	502	189	126	217	205	
ESR		25417											29186
	Intnl								39	38	40	37	
	NZ								29	14	30	29	
	Total		n.a.	11	12	30	21	60	68	52	70	66	
Crop & Food		25844											32232
	Intnl									129	131	139	
	NZ									27	31	35	
	Total		71	80	102	93	105	134	113	156	162	174	
Landcare		28704											42742
	Intnl									250	289	269	
	NZ											114	
	Total		80	200	n.a.	n.a.	160	220	200	250	289	383	
NIWA		35835											81312
	Intnl								234	313	290	269	
	NZ								147	170	165	184	
	Total		n.a.	n.a.	n.a.	n.a.	n.a.	367	381	483	455	453	
FRI		28660											39442
	Intnl								60	77	68	81	
	NZ								43	40	81	64	
	Total								100	117	149	145	

Professor Mansfield. Outstanding science and successful market innovation often go together in our experience.[19]

Are incentives on CRIs correct and what could govern all-round healthy behaviour? If the CRIs are held *de facto* to a purely financial result then the behaviour will be one of producing money where CRIs can, i.e. in the *discovery* part of the spectrum possibly by doing derivative science in contract research. Performance criteria should therefore relate *in reality* to science output as well as the financial bottom line. Science performance as science is always very difficult to measure and we suspect is not measured adequately in the current measures adopted by CCMAU in their requirements for non-financial performance indicators in CRI annual reports and is something a government regulatory department cannot readily judge.[20] Though assessment of science and colleagues is a well-honed international skill amongst scientists in a time proven system, its proper working requires understanding of the impact of publications. Impact, that is the extent of incorporation of a piece of work into the scientific forefront, often cannot be assessed immediately and will not be assessed at all unless it comes from papers genuinely in the international arena, i.e. those papers that are listed on major international databases such as PubMed. Impact is not identical to appearance of papers on citation indexes (e.g. 'methods' papers), and to confuse the two is a mistake.

Those outside a particular scientific field, scientist or not, gauge impact at their peril. However, for purposes of science performance measures, which we argue at least must be equal in integrity to financial measures for the reasons given, we suggest a database be established now, that in the future and retrospectively to say 25 years ago records by institution the number of New Zealand science publications in international peer reviewed journals annually that are listed on major databases like PubMed. We suggest that data are recorded at minimum as in our Table 1, but including science-contributing FTEs. We also suggest this is done for universities in a transparent manner as is (almost) presently done in CRIs' annual reports. New Zealand journals that do not appear on the major international science literature databases, conference papers, books, book chapters, reports, abstracts, papers submitted, invited presentations, papers in press, patents, citation indexes, etc., simply will not do. Such a database, properly indexed, will probably be revealing as to the impact of CRIs, research associations and universities on New Zealand science and is something any skilled librarian could maintain. Having established such a database with the necessary integrity, in our opinion there would then need to be a 'culture change' in CRI behaviour to place proper value on significant scientific innovation. We believe this is fundamental to not only CRI financial aspirations but to maintain internationally credible science and maximise the CRI social rate of return on New Zealand R&D investment[4].

Conclusion

To conclude on the model where this paper started (Figure 1), it is not at all clear that '*development'* in New Zealand CRIs can be properly funded from PGSF or, even if it is funded, whether there is a clear accounting of funding and results. In the past ten years, CRIs have received the majority of PGSF investment and therefore have been largely responsible for most of the resulting innovation. Furthermore, publication records may not be sufficiently complete to serve as a proxy for meaningful scientific productivity but they do suggest large incremental revenues of CRIs are not going into incremental internationally competitive science. That observation must ultimately raise questions of what sort of science incremental resource is going into and whether this makes competitively sustainable any of the required outcomes of CRIs.

In a separate reflection, what is clear to us is that the critical PGSF funding decisions in the '*discovery'* part of the spectrum should be appropriate to *discovery* supporting good science in generally relevant areas. The critical decisions as to economic payoff and costs are actually in '*development',* where decisions are made not only on the attractiveness of *discovery* but also on where to apply a quantum of additional money. Quantitative evaluation models[7] can probably be applied at *development* with assumptions that would make little sense in trying to apply them in *discovery.*

A second point is that the value of IP gifted by the government to its CRI wards through FRST funding may one day plug the *'development'* funding gap in our Figure 1 model. Perhaps there will be a similar lag in the appearance of these funds to the half-life of *discovery* goods in Mother Hubbard's cupboard, but until that day the funds are missing, with the obvious conclusion that *development* is stalled. The Marsden Fund is currently helpful, but by definition relates to *discovery* and not *development* in the CRIs and only helps to redress shortfalls in *discovery*. Even if IP is being generated by the combined FRST investment instruments, unless science remains internationally competitive it is unlikely to be worth much.

A third point is that government attention needs to be given to funding development either by brokering or directly. Significant incremental funding of *development* should occur but not by depleting *discovery*. It is pretty clear when government publications themselves refer to the 'Valley of Death' where such funding should go. In the CRI situation, the most important funding is PGSF and that has essentially been capped in real terms these 10 years, even though the same government policy that created the CRI model had it pegged to increments in GDP – this would have been a useful policy to have received ongoing commitment and may have helped achieve the progress New Zealand so urgently needs in its R&D outcomes. Possibly there are other government agencies that can add to resources by public-private partnerships in that area of *development* that complements the Venture Investment Fund (VIF), say in that most deathly part of 'The Valley of Death'[5], namely Phase II trials. New Zealand has a regulatory apparatus for therapeutic trials[21], it has various ethics committees, and it has ERMA. Knowing this, we also urge government efforts to achieve bilateral agreements with foreign regulatory agencies in our chief technology international markets (e.g. USDA, EPA, FDA) to avoid unnecessary duplication of costs in the really expensive parts of *development*.

Lastly, it is imperative that, in its expenditure of the very valuable PGSF funds, New Zealand policy learns the lessons of mainstream R&D economics. This monograph cites the work of Edwin Mansfield extensively, perhaps because one of us had the good fortune of spending a morning with him at the University of Pennsylvania in the 1990s, and perhaps also that his major conclusions, though not necessarily intuitive, are not controversial and represent an accepted part of economic opinion. Professor Mansfield died in 1998. The work of many, many R&D economists has shown that investment in R&D pays off handsomely. Professor Mansfield's detailed work proved that the greatest good to society from investment in R&D ('social rate of return') comes from work not targeted directly for private appropriation. He mentions in his papers that there is a connection between the most highly rated science and the best social rate of return. We wonder here whether those messages have been sufficiently heard in the New Zealand R&D environment.

Acknowledgements

We thank the Wallaceville Chief Librarian Ms Sue MacPherson for the annual report analyses and verification that the numbers are correct.

Notes and references

1 This is an often quoted rule-of-thumb, unfortunately without an obvious literature source. However, it can be developed as follows: It takes $US802M in year 2000 US capitalised dollars, or $US403M out-of-pocket uncapitalised expense to bring a 'new chemical entity' (NCE) to market approval (DiMasi, J.A., Hansen, R.W., Grabowski, H.G. 2003. The price of innovation: new estimates of drug development costs. *Journal of Health Economics 22(2)*: 151–85). DiMasi's paper refers to *'development'* as "preclinical and clinical phases I-III". Dollar allocations are distributed approx 1:2 ($US121M:$US282M in a total of $US403M) respectively. 'Preclinical' comprises *discovery* bundled together with lead substance improvements and animal toxicity trials. It is possible that in the New Zealand context, 'tweaking' of NCEs might well fit in FRST's current definition of 'Research for Industry' and therefore fits in *development*. We rely on our recent experience to estimate *discovery* cost for a promising NCE at ~$US2.5M reaching the point that the 'preclinical:clinical phases' could start. On this basis '*discovery*' would be about 2% of the 'preclinical' out-of-pocket *development*' costs making the multiplier of *'development'* over *'discovery'* in the above model, if anything, very low. If we then accounted for each *discovery* in the cohort of twenty (see footnotes 6 and 7) producing the one selected for *development*, then *discovery* costs might look like 20X$2.5M, placing the *discovery:development* ratio at US$50:US$403M, i.e. near the 1:10 ratio of the model. The DiMasi model stops at FDA approval for marketing and there follows expenses for dosage and dosage form determinations, delivery systems, packaging, manufacturing costs and marketing – hence the multiplier for '*commercialisation*' shown in our model.

2 The Office of the Prime Minister. 2002. *Growing and Innovative New Zealand*: p. 17, refers, *see* OECD R&D comparisons.

3 Ministry for Research Science and Technology. 2001. *New Zealand Research and Development Statistics 1999/2000.*

4 These weightings somewhat reflect the views of eminent R&D economists but if anything do not reflect the value of fundamental research enough. R&D investment in privately appropriable research in 37 innovations resulted in private returns greater than 25% but the 'social rate of return' of basic R&D, not directly appropriable, is much greater than that; in the order of 70% (Mansfield, E., Rapoport, J., Romeo, A., Wagner, S., Beardsley, G. 1977. Social and private rates of return from industrial innovations. *Quarterly Journal of Economics 91(2)*: 221–240; Mansfield, E. 1991. The social rate of return from academic research. *American Economic Review 81*) and see footnote 7. R&D investment targeting to increase directly the competitive stance of the private sector is unlikely to work well (Cohen, L.R., Noll, R.G. 1994, Sep. Privatizing public research. *Scientific American*) precisely because the main economic benefit comes from widely shared technology.

5 Foundation for Research Science & Technology. 2002. *Progress and Achievements Report, Nov 2002,* p. 6 refers.

6 Katharine Ku, Director, Stanford University, Office of Technology Licensing (personal communication, 2003). Stanford has averaged 220 disclosures pa (in 22 years of the OTL operation), 35% of which are licensed and 1.5% (73) have realised significant royalties (over $US100K) and about half of these over $US1.0M. Stanford University OTL is one of the most active in the US and one from which valuable lessons can be drawn.

7 Three companies involved in chemicals and proprietary drugs had an average probability of 12% that an R&D project would result in an economically successful process or product (Mansfield, E. 1981 (Nov–Dec). How economists see R&D. *Harvard Business Review*.) though there was a 30% chance projects would reach technical completion and be commercialised unsuccessfully. In 37 innovations, the private rate of return median was 25%, but the social rate of return median was 70%. The author noted an underinvestment in R&D inherent in these figures.

8 Evenson, R.E., Waggoner, P.E., Ruttan, V.W. 1979. Economic benefits from research: an example from agriculture. *Science 205: 1101–1107.*

9 Scobie, G.M., Eveleens, W.M. 1987. The Return to Investment in Agricultural Research in New Zealand: 1926-27 to 1983-84" *Research Report 1/87: October 1987, ISBN: 0-477-03092-0.*

10 Mansfield, E. 1991. Academic research and industrial innovations. *Research Policy 20*: 1–12.

11 US Pharmaceutical Research and Manufacturers Assoc. web page.

12 Colin James. 2003. Into the Valley of Death…(*NZ Herald,* Tue 14 Jan 2003) commenting on Canadian province R&D policy and running *discovery* dry by diversion of funding to *development*.

13 IGNS in the last several years has not separately reported refereed papers at all – only a total of refereed papers and conference papers.

14 Reserve Bank figures for CPI averaged 1.96% in the five years 1994 –1998.

15 Goldfinch, S. 2001. An assessment of the research performance of the Crown Research Institutes using bibliographic measures. *New Zealand Science Review 58(3)*: 102–110

16 CCMAU (Crown Company Monitoring and Advisory Unit). *Policy for Identification and Monitoring of the Key Financial and Non-financial Performance Indicators in Crown Research Institutes*. The policy does identify listing on publication databases as important but it is unclear what databases and whether this is complied with.

17 Mansfield, E. 1991 (Nov–Dec). Social Returns from R&D: Findings, Methods and Limitations. *Research Technology Management*. The author noted a link between the characteristics of the researchers (most highly rated) and the rate of return.

18 Such targeting in the New Zealand circumstance would need to be supported by quantitative econometric study. Edwin Mansfield; Wharton School of Economics. 1993. *Research and Development: Expenditures, social returns, management and uncertainty.* Monograph commissioned for AgResearch.

19 Pers. comm., Prof. David Bibby (formerly Industrial Research Ltd, now Dean of Science, Victoria University of Wellington), and from one of us (PHA).

20 Ministry of Research Science and Technology with assistance from the Crown Company Monitoring and Advisory Unit. *An Appraisal of Crown Research Institutes, 1992-2002*. This paper analyses the performance of the CRIs in their first ten years and is useful for analysis of financial performance. Science performance reported is anecdotal and relies for publication data on a separate study (see footnote 15).

21 'SCOTT Committee': Standing Committee on Therapeutic Trials.

New Zeal, and why we need it

Steve Thompson
Chief Executive, Royal Society of New Zealand

The views expressed in this paper are not necessarily those of the Royal Society of New Zealand.

Is growth good?

How does a country grow in terms of overall wealth and well-being of the economic, social and environmental aspects of its integrated whole? Early economic attempts at divining an 'engine for growth' saw land and labour as the two prime requisites, and they were probably right in a sparsely settled New Zealand of a century or more ago. Then, economists added capital to the list as factories began to churn out more and more of the wealth of a country. Labour was seen merely as a means of operating machines.

In the mid-1900s, economists noticed that their explanations missed the mark widely when looking at growth over the long term, and they added another variable to try to make the models work: technology. They could not find a way to measure the input of technology, but just assumed that it must be the 'dark energy' (in today's astronomical parlance) which would account for world's astonishing continued growth.

But, economists said, the law of diminishing returns would have to kick in at some point. However, that evil day is put off by the way that GDP is currently calculated, where such things as oil spills and nuclear tests count as *increases* in economic activity, and where deforestation and traffic accidents count as *additions* to GDP. In fact every business knows that spending money on repairs and clean-up counts as a cost, not as income. Every business also knows how to value its assets. A forest company knows it has to regenerate harvested trees if it wants to stay in business. But countries do it differently. When they calculate GDP, they count the billions of dollars to clean up something like an Exxon Valdez oil spill as a plus. When they see the last tree cut for paper, they count it as an addition to GDP. If we calculated GDP as if the Earth were a family business, we might find that much of today's 'growth' is short-term and short-sighted in nature. Dennis & Donella Meadows re-opened the spectre of diminishing returns in their book 1972 book 'Limits to Growth'[1], which brought the notion of exhaustible resources into our consciousness (a theme which Thomas Malthus had first espoused in 1798).

Just Imagine!

US Economist Paul Romer[2] took a new look at the problem in 1986. He postulated that the 'dark energy' was really our ability to imagine! Imagination was the key variable which might explain why growth was not slowing down as we met diminishing returns to our stocks of natural resources, labour and capital. Countless opportunities exist for our imagination to create new ways to meet our needs and desires.

Romer's second observation was that the development of a new idea or product can be very costly, but its replication and distribution may be very cheap. But new ideas and the resulting technology have proven to be the mainspring for economic growth in those countries with high growth rates. New ideas provide a way round the limited thinking of diminishing returns, and offer a powerful springboard to new prosperity. New ideas depend upon *people*, while product replication and distribution depends largely on machines.

Imagine: Science in government policy

Science is now an essential component of some of the biggest policy issues facing governments today, such as food safety, water quality and global climate, but government remains structured to emphasise economic advice with relatively little science input. The views of scientists, including social scientists, are needed to advise on what is known and what remains unknown or subject to risk. Policy options should be based on good scientific evidence, but responsibility for policy must ultimately lie with governments, rather than with working scientists.

Imagine: Basic research

Recent evidence suggests that perhaps as many of our wealth-creating (and avoidance of diminishing returns) ideas come from curiosity-driven research as from targeted research

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– an idea borne out by some of the world's largest private investors in university research. When asked the nature of their investment, they are likely to reply that it is more for the goodwill, keeping abreast of new theoretical developments, and keeping an eye open for outstanding talent, than it is for the actual results of the projects funded. Arnold & Thuriaux[3] conclude that the major contributions of basic science are research skills, methods and instruments, and professional contacts. Scott et al.[4] support their conclusion with their report that about a fifth of industrial R&D managers report using instruments or techniques generated from research done by the public sector. Several other benefits are cited, such as enhanced credibility for firms using independent testing facilities at universities. Cohen & Levinthal[5] state that we now understand that R&D has two faces: a *learning* face which acquires and absorbs technology; and an *innovative* face which seeks and applies new knowledge.

Imagine: Turning ideas into growth

Most discussions on science and technology policy in New Zealand begin and end with the money: we need more of it, either government money invested in different parts of the innovation spectrum, or private sector money to achieve a quantum increase in industry innovative activity.

All that is true, especially in terms of private sector investment. We do not have much evidence in New Zealand, but a recent paper by Guellec & Van Pottelsberghe[6] investigated the impact of public sector R&D funding on business R&D in 17 OECD countries. They found that every dollar of government investment stimulated on average a further $0.70 in private sector research. However, they noted that this effect did not continue forever. Public R&D began to crowd out private research when government R&D exceeded 13% of the business R&D, and substituted entirely at 25%. These figures are alarming in New Zealand's situation, where government investment exceed industry by about 200%, and point to the urgent need for government to devise ways to use its funding to maximise its leverage with industry. Guellec & Van Pottelsberghe found that the transfer of technology from university research is improved when government funding of business research is increased, and this might be broadened in New Zealand to include Crown Research Institutes – a peculiarly New Zealand structure.

Government makes much of the need to encourage industry to invest more in R&D, to raise New Zealand from its current private sector investment of 0.4% of GDP. GDP is running at around $120 billion, which implies that, for example, a mere doubling of private sector R&D would need to induce a further $480m investment out of industry.

Technology New Zealand requires 50:50 joint funding, and the new consortia aim for something similar, but new government money in these two areas amounts to about $10m, which will prise a matching $10m out of industry. The $100m Venture Investment Fund requires matching by $200m from the private sector, but this is slow in coming, and even optimistically, might raise some $50m of new private money per year. FRST's Research for Industry (RFI) fund should encourage more private investment, but it has no firm rules on private sector contributions. A pure guess might suggest that it has potential in the medium term to leverage $20m per year.

All that totals to an extra $90m of private sector investment in R&D annually, which falls short of the quantum leap that New Zealand needs, especially if it hopes to reach or surpass the OECD average of 1.2% of GDP invested from industry. At current rates of progress it would take us 16 years to get there. One way to encourage industry participation would be to make a portion of government funding available for industry lead applicants only.

Interestingly, Guellec & Van Pottelsberghe found that tax incentives do encourage business R&D, especially if they are stable over time, but they also found that direct government funding of business R&D and tax incentives are substitutes for each other. In New Zealand this is evidenced by the government's $8.5m Grants for Private Sector Research and Development (GPSRD) scheme, which is supplemented by a further $17m from successful applicants. A tax incentive would, of course, be far more widely available than the GPSRD programme.

Unleashing imagination

So is growth good? Yes, if imagination is brought into the equation. Without imagination the world would indeed hit diminishing returns, and has already done so in instances where blinkered thinking has led to exhaustion of some of the world's biological stocks, and to pollution of some vital resources. But, by adding imagination, a factor not limited by diminishing returns, economists can ingeniously keep growth going forever, though not in ways we have traditionally valued. Instead, we shall come to value the cerebral, the virtual and the vicarious, rather than the joys of mining another mountain for its minerals.

Just ahead of this year's 'Knowledge Wave' conference, New Zealand's Minister of Research, Science and Technology published a slim document called the 'i^3' challenge. His three '*i*'s were ideas, innovation and investment – all aspects of increasingly 'applied imagination'. So, let's add a fourth '*i*' to the beginning of the list and start with imagination.

Imagination broadens and deepens the scope of the policy debate into a more fundamental question: can the policies of a nation enhance or diminish the imaginative and creative capabilities of its people? Yes, of course they can: we know that repressive regimes can succeed in dulling the spirit of the most stubborn of minds, but we have put less thought into policies to stimulate creativity. It's a big ask, of course. It starts in primary school and family environment. It moves through inspirational teaching at secondary levels and role models for teenagers. By the time we reach tertiary level, hard-headed decisions on careers surface, and assurance of joining an exciting sector, with the promise of living in vibrant communities, begins to play a role. As we enter upon a career, we need to know that our business, community and government leaders will do everything they can to support creative ideas.

Opportunities to blunt our imagination during that long journey are rife. From the parent who says "science is a waste of time", to the adviser who says "you're not clever enough", or "those jobs are not for the likes of us", or the employer who says "I can't afford to spend money on useless experimentation", to the local or national regime which can do more to create the infrastructure and conditions needed for a creative society to prosper.

Unleashing excellence

Science policy is about more than the money. It's about inspiring young people. It's about making sure that society fully understands what its scientists and technologists are doing, and what controls are needed. It's about creating an environment where scientists can produce their very best, without undue fear of redundancy by whim. It's about creating a thirst for new ideas in industry, and lastly, it's about ensuring that the best scientific advice is routinely used as input to government decisions affecting all walks of life.

Scientists work in the most uncertain of all human endeavours, transcending risk into the dimensions of pure discovery. The Royal Society is at the front end of that challenge, and is one player among a whole team of players in making sure that we invest in the best, and unashamedly grow tall poppies. In a nutshell, we need to do three things to unleash our collective imaginations:

- Work with young people to create and nurture that essential spirit of imagination.
- Promote a knowledgeable and critical awareness of the opportunities, and ethical and societal issues, arising out of science and technology.
- Encourage and enable scientists and technologists to excel in the creative work they do.

Readers of Science Review do this work because we share a passion for knowledge and want to support the development of others. We understand how vitally important the work we do is for New Zealand's future. The Royal Society has presented several advice papers to government this year. We have run several successful communications courses for scientists, and we have revised our code of ethics. We know that more science teachers are joining their professional association. We have 650 young people in our Young Achievers database, all of whom receive regular updates about science, technology, and careers. Clippings surveys show that the Society generates about one-third of New Zealand press coverage we receive on science and technology and overall coverage has increased.

The Society has made major inputs to the development of legislation and programmes on genetic modification and hazardous substances, Centres of Research Excellence, and scientists' career paths. The journals published by the Royal Society have re-established editorial boards, and the journals are available electronically. We have worked with Industry New Zealand to administer their new Enterprise Culture and Skills Activities Fund. Industry New Zealand is also supporting a Royal Society-initiated project to examine leadership qualities in New Zealand. On behalf of government we currently administer the Marsden Fund and the Centres of Research Excellence selection and monitoring process.

In formulating where we go from here, the Royal Society places particular emphasis on:

- Leadership in promoting awareness of S&T and dialogue with all communities and age-groups in New Zealand.
- Strengthening our advice to government and others on S&T matters.
- Communication among, and enhancing our value to, all our members and the wider S&T community in New Zealand.
- Working with Maori to strengthen engagement in S&T.
- Strengthening the services to, and contribution of, Social Sciences to the Royal Society.
- Building a viable and independent Society.

The challenge we place before you, *cher lecteur*, is to contribute your own talent and effort to all of this, and put excellence to work as a beacon and inspiration for all New Zealanders.

Conclusion

In seventeen years, Romer has not changed his view on imagination. He repeated it at Auckland's Knowledge Wave conference this February. Fellow US economist, Richard Florida, put it a different way. He noted some disturbing recent trends of increasing isolationism and erosion of trust between individuals and organisations (and, it could be added today, countries). To counter this, he saw scientists as playing a vital part in his real engines of growth: connectedness and creativity. As the New Zealand Herald noted at the time, creative people might be artists or rock musicians on their way to becoming entrepreneurs, but they want to be around other creative people. Dr Florida cited his 'Bohemian index', which showed that cities with vibrant and diverse populations and lifestyles achieve the fastest rates of technological development, new company formation and economic growth.

The main message from these speakers was that quick fixes may help, but the main driver for a country's growth is the nurturing of talent, and the provision of a creative and supportive environment. Government is undertaking more work to flesh out the three '*i*'s of ideas, innovation and investment, but the bullets listed under the 'Ideas' heading stressed that ideas (and funding) must contribute to government strategies. They also talk about the need to evaluate the outcomes.

Now – is this the sort of vibrant creativity we are looking for?

References

1 Meadows, D.H., Meadows, D.L., Randers, J., Behrens, W.W. 1972. *Limits to Growth.* Potomac Associates, New York.

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3 Arnold, E., Thuriaux, B. 2001. Contribution of basic research to the Irish National Innovation System. *Science and Public Policy 28(2)*.

4 Scott, C., Steyn, J.A., Geuna, A., Brusoni, G., Steinmueller, W.E. 2002. *The economic returns to basic research and the benefits of university-industry relationships.* Science Policy Research Unit (SPRU), Sussex University.

5 Cohen, W., Levinthal, D. 1989. Innovation and learning: the two faces of R&D. *Economic Journal 99*: 569–596.

6 Guellec, D., Van Pottelsberghe, B. 2000. The impact of public R&D expenditure on business R&D. *OECD STI Working Papers.*

Quality investments drive performance

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Investment decisions and why they matter

An often forgotten (or at least under-recognised) determinant of economic growth, profits, or non-profit outputs is the quality of investment decisions made by nations, businesses, and non-profit organisations respectively. High-quality decisions mean growth for economies, profits for companies and achievement of organisational purpose for non-profit organisations. Conversely, low-quality decisions ultimately mean economic decline, losses, and organisational failure[1].

While 'investment decision' is a term normally associated with the commercial world, and therefore is often seen as limited to a narrow financial focus, its relevance is in reality much broader. It is a term with very wide meaning and general application. Investment decisions are simply the choices made nationally, in business and in non-profit organisations, about the disposition of resources available to those entities. Such resources include all manner of assets; natural physical resources, people, intellectual property, financial resources, capital assets, time and so on. They are real inputs that, if used in sensible and carefully calculated ways, will yield benefits beyond their input value. When that happens economic growth, profits and the realisation of organisational goals result.

To illustrate the wide meaning and general application of the term 'investment decision' consider the types of choices about resource use that nations, firms or non-profit organisations may face. In the case of a nation, for example, there are choices about building infrastructure to support economic activity versus direct participation in economic activity through state owned or sponsored businesses. For a company there are choices about building brand value and promoting products to markets versus expanding capital plant to improve manufacturing capacity. For non-profit organisations, such as welfare bodies, the choice may lie between focusing on education versus implementing remediation programmes. Within each of these choices are further choices about how best to improve infrastructure, invest directly in business, promote products and so on. All these choices concern real resources, applied in different ways to achieve the outcomes desired. Poor quality decisions will mean that desired outcomes are, at best, only slowly or partially achieved, whereas good quality decisions will support the rapid and full attainment of target goals.

Some may argue that many factors other than the quality of investment decisions will influence economic, business and organisational performance. For example, trade rules, weather, demographics, competing products, skill levels, available physical resources and the like. However, these other factors are best viewed as variable components of the investment environment within which investment decisions are made. As the investment environment changes, what constitutes a quality investment decision will also change. This is why, to the extent possible, it is important to have an undistorted investment environment. Quality investment decisions will respond to environmental circumstances. If these circumstances include distortions that encourage investments away from their otherwise best use, then the investment decision will be a quality one for the environment, but sub-optimal compared to what could be achieved without the distortion.

In exactly the same way that investment decisions are key to national economic, business, and organisational performance, they are also key to the performance of the science system. The publicly-funded science system in New Zealand has four high-level goals[2]:

- Knowledge: 'Investing in people and skills to ensure new knowledge for New Zealand'
- Economic: 'Investing in research to improve New Zealand's economy'
- Environment: 'Investing in research to enhance the environment of New Zealand'
- Social: 'Investing in research to improve social well-being in New Zealand'.

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These goals consistently refer to 'investing'. This bodes well for achieving the goals because it indicates recognition of the importance of investment decisions and the allocation of resources to goal attainment, although this has not always been the case. During the 1990s it was far from universally accepted that research funding was an investment issue, and for most of the 1990s, use of an investment model[3] for allocating research funding was dismissed in favour of alternatives[4]. There was a clear contradiction in this in that funders routinely made choices between projects, thereby implicitly valuing one project higher than another, but rejected the notion that it was possible to measure the investment value of one project over another. Even currently, attempts to directly measure investment value are rarely undertaken. Rather, consensus judgements and proxy measures are used evaluate quality. For example, the Performance Based Research Fund (PBRF), being introduced to fund research in tertiary education organisations, uses research quality, measured in various surrogate ways, as a proxy for investment quality.

Achieving quality investment decisions

The investment concept for research funding is now well accepted, and indeed is reinforced in the government's recently released *i^3 Challenge*[5]. The next issue, if it is accepted that the quality of investment decisions is a key determinant of goal attainment, is the process by which investment decisions are made and the quality of the outcome that may be expected. The process of investment decision-making comprises the analytical approach used, and the system within which it is applied.

By and large public sector research funders employ broadly the same approach to making investment decisions. In the case of the Foundation for Research, Science and Technology (FRST) this is characterised by[6]:

- Development of investment strategies, based on sector and end-user strategies, that are designed to achieve the government's RS&T goals.
- Development of research programmes aimed at delivering the objectives contained in the strategies.
- Allocation of research funds within programmes using investment criteria and employing the expertise of reference groups.
- Performance monitoring.
- Evaluation.

This is a committee-based approach that uses experts to advise FRST on the relative merits of alternative investment bids within the context of FRST's investment strategies and investment criteria. FRST, however, makes the final investment decisions. The approach is sensible in that it attempts to evaluate investment proposals against pre-determined goals and strategies, although it does not do this quantitatively using investment models. Nevertheless, the approach is undoubtedly investment-oriented, and there is no questioning the expertise and commitment of the expert volunteers that advise FRST and other funding agencies. The approach may therefore be reasonably expected to produce quality investment decisions, particularly if a clear focus is maintained on the necessity to estimate value. In FRST's case 'value' is the ability of project proposals to meet the established investment criteria and deliver on the stated strategies, for those criteria and investment strategies to be confirmed as the best way to achieve the nation's research goals, and for those goals (or perhaps more importantly the objectives underlying the goals) to be confirmed as the highest value use of the nation's research resources.

Regarding the second component of the investment process, the system within which analyses are conducted, the same test for quality needs to be applied. The system choices are generally between centralised versus diversified decision-making.

Theory, common sense and history all suggest that diversified decision-making processes out-perform centralised decision-making. Diversified decision-making, through the sheer variety of players, the incentives posed by rewards to experiment, and the disincentives posed by sanctions to be prudent, allows learning, copying and constant improvement. Centralised decision-making on the other hand stifles learning and hides underperformance. If centralised decision-making could always be guaranteed to get it right and make the best investment decisions, then it would be fine as a system for allocating resources. Unfortunately, it cannot be so guaranteed, and in fact the closed and unilateral nature of centralised decision-making works strongly against quality investment decisions because rewards and sanctions are largely absent, and only one perspective on the investment environment is adopted.

Quality of investments in science

In New Zealand about $1b per annum is spent on R&D. Of this about $550m[7] is public sector spending, of which about $400m[8] or over 70%, is invested by FRST. This represents a significant centralisation of investment decision-making for public sector R&D. But is it sufficient centralisation to lead to low quality investment decisions?

About $150m of public sector R&D investments is handled by agencies other than FRST, such as the Royal Society of New Zealand (RSNZ) and the Health Research Council (HRC). This provides some diversity in decision-making, albeit quite small, and may allow learning and constant improvement to occur. However, all these public sector agencies operate under the same broad interpretation of the investment environment, as enunciated by the Minister of Research, Science and Technology and his Ministry. To this extent the diversity that may be identified is somewhat illusory.

Take, for example, investment in understanding climate change versus investment in research to mitigate the effects of climate change. The government's position (not illogically, given that it has signed the Kyoto Protocol) is that the higher value investment is in research to mitigate climate change, not further investment to understand climate change. Understanding climate change is research that, for the government, is basically completed. Whatever the case, no government funding agency is likely to invest substantially in new research to understand climate change, over research to mitigate the effects of climate change, given this government position. There is little incentive for any funding agency to support research which might challenge current orthodox views of the nature, magnitude and impacts of climate change.

The opportunity to take a dissenting investment position and encourage learning and constant improvement through diversity of decision-making is limited to non-government research investments. However, such non-government research investment is unlikely to challenge the government's position, partly as the nature of the research tends to be public rather than private and therefore of no great interest to private investors, and partly because the government has strongly encouraged relevant private interests (the pastoral sector) to invest in climate change mitigation (specifically, the reduction of methane emissions from ruminants). To the extent that this 'encouragement' is acted upon, the central view of quality research investments has been extended to investors outside the public sector and the diversity essential for quality decision-making has been weakened.[9]

Conclusions and outlook

On balance, the quality of R&D investment decisions in the public sector is likely to be assisted by the analytic approach used to evaluate investments (especially compared to the past), but hindered by the centralised decision-making process. As a result there is likely to be room for improvement. Having said that, however, this is not an uncommon phenomenon. It simply makes the point that, having accepted the quality of investment decisions as a key determinant of successfully achieving prescribed outcomes such as economic growth, it is important to be constantly vigilant in the search for ways to improve the system of decision-making. If diversified decision-making is accepted as superior to centralised, then progress must be made to address any tendency to centralise decision-making.

In the public sector system there are some heartening signs and some concerns. Firstly, the investment nature of research funding has been strongly embraced, a change from just five years ago. While investment modelling is not used, expert consultation with both scientists and end-users is widely employed in pursuit of quality judgements. Secondly, there is evidence of moves to diversify investment decisions, notably the increase in the number of investment instruments being used, the relative freedom of research providers under these new instruments[10] to independently manage investment decisions at a micro level, and the expansion of the number of funding agencies being employed. There is still the risk of having this emerging diversity smothered by a central view of the investment environment but, the more specialised investment instruments that are introduced and the more investment players that are commissioned, the harder this will be. Thirdly, the decision to bulk fund tertiary education providers under PBRF, while not as unfettered as may at first appear given the need for tertiary education providers to respond to quality assessments and to operate under charters and profiles, is nevertheless a diversified decision environment across the tertiary sector. Unfortunately, it is not as diversified as it used to be, and there is a risk that the quality measures being introduced under PBRF will simply become targets leading to a greater alignment of outputs to measures but not necessarily to an improvement in the quality of investment decisions. Fourthly, there appears to be a genuine commitment to, and focus on, ensuring that public sector research investments yield real and measurable benefits for New Zealand in accordance with the established national goals. The *i^3 Challenge* makes this very clear. If this commitment is followed up by ensuring that the system within which research investment decisions are made is such that quality investment decisions result then New Zealand should expect rewarding returns from its allocation of public sector research resources.

Notes and references

1 In a more general context, the quality of investment decisions determines success in achieving the goals of an entity, whatever these may be. For discussion purposes these are assumed to be economic growth, profits and non-profit outputs, but it is certainly acknowledged that other goals may exist. In the case of a nation, for example, while economic growth is a fairly ubiquitous goal, there will be others such as equity and security, and these other goals may often be in conflict with the economic goal.

2 http://www.morst.govt.nz/

3 Conventional investment models employing various techniques to address risk and uncertainty, and which acknowledge the data problems of, in particular, social and environmental projects.

4 In 1995 the Science Priorities Review (SPiR) developed a 'quantitative/qualitative' methodology for determining science priorities. This involved a Delphi survey, a weighted six-factor scoring model (adjusted for 'other considerations') and direct allocation of funding to outputs. The methodology did not estimate benefits against cost. Similarly, during this period, FRST allocated research funding based partly on 'audit trails' (a record of previous funding) and partly on set criteria such as benefit to New Zealand. Again, benefits were not measured against costs to identify the best investments.

5 Minister of Research, Science and Technology. 2003. *The i^3 Challenge.*

6 http://www.frst.govt.nz/about/investmentprocess.cfm

7 Ministry of Research, Science and Technology. 2001. New Zealand Research and Development Statistics 1999–2000,

8 http://www.frst.govt.nz/about/index.cfm

9 Since this was written, the government has moved beyond just 'encouraging' the pastoral industry to invest in research on methane emissions from ruminants, to imposing a compulsory levy on the industry to fund such research.

10 In particular, CoRES and Research Consortia.

Steering a path through the current New Zealand science funding environment

Cath Kingston
HortResearch, Hawkes Bay

This article represents a personal opinion and does not necessarily reflect the view of the organisation I work for.

Much has been written about the pros and cons of the current science funding environment in New Zealand. Working within a science organisation that secures a relatively large proportion of its funding from government sources, it is difficult to review, in an unbiased way, the effects of the current science funding environment on productivity and morale. This article will not be an attempt to present figures that support any particular point of view: what I want to try to explore is why scientists generally regard the current science funding environment as restricting innovation and motivation and discouraging new graduates from science careers.

It is a sad fact of life that there will always be too little funding available to support all the scientific ideas and initiatives proposed. A limited pool of funding is not a new problem for science. In the days of DSIR and MAF Technology there were always scientific groups within the organisation who felt disadvantaged and under-funded compared to other groups. There were always fashionable and unfashionable groups, depending on the policies of the government of the day, personalities and political nous (by that I mean the ability to work out the right way to attract attention and funding). Overall, scientists operated with shorter and more direct communication channels: they 'only' had to sell their ideas to organisational managers to get funding approval for new innovations and technology. This 'advantage' of bulk funding has to be weighed against the potential lack of focus and restriction in vision when science activities are prioritised and funded by MoRST and FRST respectively, operating in comparative isolation.

The new competitive funding system was introduced to increase strategic focus, thus maximising outcomes for the economy, environment and society. Theoretically, this enables a myriad of great ideas to be prioritised and funded subsequently in a more transparent fashion, taking into account the priorities that the policy arms of Government have put in place. The establishment of defined output areas has provided a focus for scientific research but, at the same time, has constrained, possibly even provided a barrier to, new innovation.

But to get back to transparency for the moment: is the funding system more transparent? I believe it is, although possibly only marginally so. However, like all systems that rely on human input, this system will always have failings, being subject to personal opinion, beliefs and inconsistent actions – no matter how carefully managed. The real question in my opinion is whether we are managing the system to maximise the incidence of 'good productive science' and to minimise the level of inappropriate human behaviour (such as ill-informed decision making or even worse, bias). Do we have the right checks and balances in place? I am not convinced that we do. Making the right decisions is particularly critical when funding for science in some areas is being reduced. The fall-out from funding cuts is real and irreversible in terms of lost opportunities, but more especially in respect of lost science capability. It is critical then, to make appropriate funding decisions that will not come back to bite us in the longer term.

Perhaps one of the main reasons for a growing level of dissatisfaction with the current system is the level of uncertainty (or science career fragility) that is created by the funding allocation process. The only certainty is that the rules will change regularly, and such changes will be accompanied with a stack of 'user guidelines' that are mind boggling in both volume and complexity. As if scientists didn't have enough to read during the course of a working day! Not only are Government priorities altered regularly, but so are the rules of engagement. In the beginning, funding allocated to Crown Research Institutes (CRIs) could only fluctuate within a given percentage range after any funding round. Within a few years this percentage restriction was lifted (although audit trail was taken into consideration when making funding decisions). This was of some comfort to the science community in respect of impact on scientific careers: under this scenario, to displace existing programmes, new programmes had to be notably better (whatever this means!). It was rare for existing programme funding to be reduced to zero. Rather, programmes that were not considered to quite measure up were usually given a funding cut to signal that they needed to sharpen up their act. Now we have moved on to a system that appears to be 'audit-trail blind': we are ad-

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vised that all research will be considered on its merits – past history is exactly that, a thing of the past. This has created considerably more instability in science funding terms. What is considered good one year can be discarded the next. What level of continuity does that create for an activity like research that is inherently long term? At the personal level, if you have an off year when writing a funding application, this can become a terminal sentence for an otherwise exceptional science career.

I don't for one minute envy those who are in the decision-making seat. A written funding application provides so little scope for a research team to showcase its science, especially now that most of the application deals with economic, social and environmental outcomes, in addition to justifications for these outcomes expressed in various ways. The decision-makers have to make a call on the value of the science with a very limited information set. The increasing complexity of the funding application has seen scientists become more and more diverted from pursuing science. The discussions, brainstorming, coordinating between departments and organisations, etc., required to complete a successful application represents downtime from what scientists regard as the most important activity; namely, science. The evolution of the system, then, has been accompanied by the evolution of scientists into professional funding application writers who can make a compelling case for the social, environmental and economic impact of every scientific pursuit. As a decision-maker, it must be more and more difficult to differentiate between increasingly cunningly constructed applications, and choose the science, that will deliver the outcomes Government expects. It seems to me very easy to be duped by 'word-smithing'.

We may not care to admit it but it is necessary from time to time to review investments, including those in research. Sometimes this will require funding shifts, but is the rate and direction of shift appropriate? In some cases it may be happening too fast. Future opportunities may go unrecognised by prescriptive 'scientific investment signals'. Funding shifts, particularly decreases, are generally widely advertised ahead of time. However, scientists remain an optimistic lot! Even in funding rounds where it is well known that reduced levels of funding are available, scientists always anticipate that some other research organisation will bear the brunt of the cut and their science will be left relatively unscathed. It doesn't seem to matter how many times experience teaches otherwise, they still like to believe that their science is somehow better than somebody else's science. This self-belief in one's ability is important. In general, while science embodies some level of collegiality, nobody will regularly promote your research ahead of their own. Consequently, if you don't believe that the science you are doing adds value and will deliver results, then you definitely won't be motivated to write a funding application. You also need to be motivated to work at research day in and day out, go through the rigour of repeating those experiments, crunching those numbers and interpreting those statistics so that you can be the first one to publish the exciting things you have found. The intangible rewards of advancing scientific understanding and achieving recognition amongst your peers must surely be one of the reasons people pursue a career in science. Very few people are attracted to a career in science in New Zealand for the remuneration alone! I'm not proposing that we go back to public service days, but we should note that the security that used to be attached to a science career also kept many people in the profession. Given the level of personal investment made by scientists in their education, little wonder that the current funding system is not viewed very favourably!

To obtain the funding to support work that allows you to experience that thrill of discovery, you have to make a funding application. The regularity with which funding applications need to be made, coupled with the amount of information needing to be read, digested and arranged (and rearranged many times) before you can submit a funding application with even a modest chance of success, is enough to wear down even the most enthusiastic of scientists. Then, despite your best efforts, there are no guarantees. Success is not a given and a lot of pain is generated before, during and after a funding round. You struggle to make sense of Government's signals regarding research priorities. You believe that the research you are doing meets the criteria and creates value in economic social and environmental terms, so you work long days to write a funding application outlining why your research is important – all to the detriment of getting on with the science. Then, you learn that your funding has been reduced or, even worse, disappeared altogether. It hurts to be told that the research area you may have invested a good part of your career in exploring is not regarded as a high priority. This might be true, but may also be a consequence of the system failing to recognise the potential value of your scientific innovation. It is frustrating to have to spend so much time justifying why you should pursue your science rather than actually pursuing it. It seems unfair that the advances the industry sector was able to make, due to those incremental changes generated by your research, are not significant or substantive enough to grab the attention of decision-makers. Does this sort of rejection make you consider re-training in another area of science that is currently fashionable? Probably not! Does this sort of rejection make you consider an alternative career? Increasingly so!

As a rider to the last few comments, it has to be acknowledged that scientists are generally not public relations experts. Much of the excellent science in New Zealand is often poorly promoted to end users and its value under-rated. Often, its value becomes apparent only after the research team has been disassembled and the development barriers encountered by industry groups cannot be overcome. A bit too late then, to try and turn the clock back.

Impacts on CRIs appear to have been variable but few have avoided significant funding shifts within at least one area of scientific endeavour. Unfortunately, many of these funding shifts don't affect just one or two staff. Increasingly, many involve larger research teams. The potential to lose science capability is therefore quite substantial. How do we avoid this? Not an easy question to answer! Once the initial shock of funding rejection has passed, the perennial questions that trouble science administrators everywhere arise. What to do with a wealth of talent, expertise and corporate memory in an area that has, at the push of a policy analyst's finger on a computer key, become unfashionable. Retain staff in the hope that it might become fashionable again at some point in the not too distant future? Re-train staff into a fashionable area? Find other sources of funding? Staff retention is difficult at the best of times – more so under these scenarios. Given the emotional investment most scientific staff make in their research programme, being told that your research programme has insufficient value in relation to the prevailing funding criteria is very de-motivating. So, having staff affected by funding cuts quickly leads to disaffection despite the best intent of science administrators. Most of us know this scenario and it is not a positive one.

Resourcing new science areas or replacing staff who have left is made more difficult by the lack of graduates coming through in the agricultural and horticultural sciences in particular. The pool of talent from which to draw in the applied sciences has declined dramatically since the introduction of contestable funding in science and higher fees for tertiary students (see Rowarth & Sutherland (eds)). As a result, the average age of scientists is increasing – not a good sign for succession management.

One of the most common criticisms of Government's science funding scheme is that it encourages the production of pre-meditative applications: those that outline what work will be done and predict the outcome. Not much room for creativity here, except in predicting outcomes. In other words, this process stifles innovation. Wouldn't it be far better to include past achievements as one of the key criteria in assigning future funding? Perhaps this is an old system, but it would encourage the development of teams and the mentoring of younger staff; in other words, the collaborative science within and across organisations that the system claims it wants to encourage, but so far is falling short of delivering.

It would be inappropriate to end this article on a depressing note. There are some wonderful people doing some extraordinary things in our research organisations. These people are an incredible resource for the wider community. Increased stability in the science funding environment would enable them to get on and do something that has a good chance of delivering benefits. Currently, they feel trapped in an endless cycle of funding justification. I personally look forward to some new initiatives to get innovation, funding (career) stability and fresh new faces into science for the future well-being and prosperity of our economy. Key to this will be 'bending the ear' of current policy makers – we'll do our best to fit this in between funding rounds!!

Acknowledgements

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Directing the innovation system to create economic and social value

Nigel Kirkpatrick
Industrial Research Limited

However you look at it, New Zealand has scored much success over the years from its science and technology-based innovations. Our science has always been strong, and we've punched well above our weight in many areas. However, more than ever we have to take the great science we do, turn it into technology and turn that into economic wealth.

We have all the makings of a successful innovation system. We have world-class environmental and ecological research. We have world-leading agricultural research. We already have world-class industries in areas such as ICT, engineering and biotechnology.

But, in making the transition from a commodity-based economy to one based on high-value, knowledge-based business, we need to ensure that we have the right frameworks, processes and environment in place to strongly support and encourage the development of those innovative, high-value industries.

The innovation system needs to be directed to this end to create real economic and social value for New Zealand.

Clarity begins at home

In talking about innovation in New Zealand, however, I prefer to talk mostly around what I know best – the part of that system within which I work – Industrial Research Limited.

In our case, if we measure success in terms of the economic contribution Industrial Research has made to New Zealand in the eleven years of its existence, I think the report card would read: 'Doing well, could do even better'.

On the 'doing well' front, while I could detail all the real and significant successes Industrial Research has achieved in just over a decade since the science reforms, this could be misconstrued as blowing one's own trumpet. Suffice it to say that we've made great progress in developing the business and positioning ourselves for the future. Moreover, in terms the science itself, we can quite rightly take considerable pride. Some of our science is genuinely world leading. Most is unarguably world class.

So, in terms of 'doing even better', I contend that, while we do indeed have very good science, we could do better at capturing value from it.

In Industrial Research's case we have decided quite clearly that our role is to create significant economic value for New Zealand, utilising science and technology. We have determined that 'significant' means making an identifiable impact on GDP.

Based on a realistic assessment of the potential contribution that could be made to the New Zealand economy by several technology businesses already identified, we see a $500 million target as achievable within the next decade. But, let's be quite clear about this, we're not talking about turning Industrial Research into a $500 million a year business. We're talking about the contribution to New Zealand resulting from the development and take-up of our technologies. Some of this business we will own. Much will be owned by other companies. What is important is that it will ensure that the very clever science we undertake is making the contribution to New Zealand Inc. that it deserves.

High value products

In terms of the technologies themselves, it's fairly obvious that we need to concentrate on high-value products – pharmaceuticals, ICT, advanced materials, etc.

New Zealand as a whole has done extremely well at developing, and profiting from, our agricultural-based sciences and technologies over the last 50 to 100 years. We need to broaden this success into other sectors.

A tonne of good quality wine can earn us $10,000. Contrast this with the new pharmaceuticals such as Prosac or Viagra which sell for about $26 billion per tonne. Or a tonne of Pentium chips at around $100 billion.

As my former colleague, Dave Bibby, would say, if Taiwan had made the same R&D investment decisions as New Zealand 50 years ago they would be the world's most technologically advanced rice producer now.

Nigel Kirkpatrick became Chief Executive of Industrial Research Limited, responsible for defining its strategic vision and building a global presence for the company's new technologies, in June 2002. Nigel's area of expertise is in leading innovation in a multinational company, returning to New Zealand with six years' international experience with the Unilever company. From 1996 to 1999, Nigel was Managing Director for DiverseyLever in Indonesia and Malaysia, and from 1999 he was global innovation leader for DiverseyLever in Zurich.

Prior to 1996, Nigel was New Zealand Manager at DiverseyLever, and before that National Sales Manager. In 1987 he was with Taylor's Textiles and 1988 he was General Manager of Fosfan Products in Auckland.

Graduating from Otago University with a degree in Chemistry, Nigel joined Unilever in 1982 in a technical capacity.

Rewarding scientists

Again from a New Zealand-wide perspective, one of the fundamentals of ensuring that you have a highly performing innovation system is having suitable rewards and recognition in place for the people who are the key to it – the scientists and technologists, without whom you'd be nowhere.

Rewards and recognition don't relate only to money, although that's an essential consideration. It's about embracing an innovation culture and recognising the contribution that some of our brightest minds are making to this country – making a science career as attractive as a career in accounting or law! This goes for scientists working in the social and environmental arenas as well, not just those in the more obviously economic-value creation sectors. Hazard identification and mitigation and understanding our unique biodiversity are equally important to a modern, knowledge-based economy.

Industrial Research's strategy

What then do we see as the necessary components for Industrial Research to achieve high-value, internationally competitive innovation?

First and foremost must be genuinely world-class science. But this science must be strategically selected and focused. Secondly, we need to develop the knowledge and expertise gained from this science into focused technology platforms. These platforms will be built from a group of different science disciplines – often, perhaps, a unique combination of skills which will result in areas of real competitive strength.

We need to develop strong partnerships with other research entities and/or other companies, both in New Zealand and overseas. In most cases we cannot ensure that we capture full value from the technology by going it alone.

Next, we have to identify key business opportunities for the technology, aligned with market needs. We have to develop these technologies into products or services – something I refer to as 'customer solutions'.

Then we must commercialise these customer solutions – take them to market.

So far it sounds fairly simple. Of course, in reality it never will be simple. It's inevitably a complex process involving many difficult decision points all along the way, with no certainties of final outcome. Take the world-class science component. Developing a world-class science capability is necessarily long-term and expensive. It doesn't happen overnight, or even in the space of a year or two. It requires critical decisions to be made many years ahead of any likely commercial applications.

Early on we have to be focused about the areas of science we're going to pursue. While it is foolhardy to try to direct and undertake science with a predictable, profitable outcome in mind, we do need to work in areas that have realistic downstream application and economic potential in the New Zealand context.

Space science and technology, for example, is unlikely to be an appropriate area for us in New Zealand. But, by the same token, we wouldn't have wanted to rule out superconducting science as inappropriate for New Zealand 15 years ago, given the lead we have developed and the applications we are now pursuing in this area.

The various science disciplines and areas of research we do decide to pursue then need to lead into coherent and synergistic technology platforms. These platforms, say in renewable energy technologies or biopharmaceuticals, require long-term support and nurturing. Likewise, we must nurture and recognise the scientists themselves.

Along the way, we need to develop a deep and genuine understanding of the market and customers to identify the needs and recognise opportunities for technology-based solutions. This is another reason for having close relationships and partnerships with industry.

From this understanding we will develop technology skill sets to address those market needs. To succeed, the business opportunity will be based on competitive advantage, which in turn results from high-quality science, IP positioning and market intelligence. From this position we will be well placed to develop the actual customer solutions.

But you can't just throw the technology solutions over the fence at this stage and expect the market to embrace them.

The 'great leap'

We have characterised this point in the process as 'the great leap'. Bridging this gap is critical.

We have decided that we as a company will usually have to walk hand-in-hand across the great leap with our technology to ensure its successful uptake. By this I mean involving ourselves more in the commercialisation stages of technology development. For us this will often mean turning the technology solution into a business in its own right. This will usually involve partnerships with other companies and investors. We will then nurture the business until it is ready to leave home. This is the difference between throwing a child out at five when it can walk and talk and feed itself, and throwing it out at 25 when it has had a tertiary education and can go out and get a job at $50,000 a year!

As such we are developing a systematic process for identifying and growing businesses. Not all will succeed, but we are confident that, given the right environment and support, we will develop some real winners to ensure that significant value is created for New Zealand. And we know we can do it!

For example, in biopharmaceuticals, we identified an opportunity, invested considerable capital in building the necessary facilities, and have within four years grown this into an $11 million per year business. Its potential is many times this. We are likely to retain some level of control until it is a very significant business by New Zealand standards. Then we'll let it go its own way. By then it will have a track record of success, a substantive ownership by people who know how to run that sort of business, and a significant number of staff who have an in-depth understanding, not just of the technology, but of the management of this type of operation.

We're taking a business through those early stages where so many businesses fail. We are now following the same model with our GlycoSyn facility. The potential for this type of fine chemicals business is literally hundreds of millions of dollars a year and there's no reason why we can't achieve that in New Zealand.

Supportive environment

In the New Zealand context an environment supportive towards developing technology-based business opportunities is vital if we are to achieve the shift to the much-vaunted knowledge economy. We need the right mix of scientific and business skills. We need to ensure that science is encouraged and rewarded as a career choice right through to university level. We have to ensure that our business training equips graduates for working in start-up companies and SMEs, not just established corporates.

We have to have a culture supportive of risk taking; one that tolerates failure and lets us learn from it.

And, as I've already mentioned, we have to have the right rewards and recognition in place throughout all walks of society to back up all the talk. We need the concept of investing in technology development to be as accepted as the idea of investing in a vineyard or rental property.

Investment – not funding

Also at a national level, I think that for too long we have talked about funding for science and technology. I prefer to regard it as an investment. Investment is predicated upon having a long-term plan. This we have. We are focusing our science in areas that underpin our technology platforms – areas that we expect to produce commercialisable, economically valuable outcomes. Those putting up the money can fairly expect a return – this is what characterises an investment rather than funding.

At the early stages of the process – developing and sustaining world-class science capability and maintaining key technology platforms – Government inevitably has a role as an investor. Its return will be long-term value creation for New Zealand.

The private sector invests in success. Its role will normally be investing at the later stages of technology development once the business opportunity is apparent. There will still be plenty of risk in getting the technology to market, but the technology solution will be defined and tangible in the way that an uncertain outcome from science never can be at the outset.

The portfolio of technology investment opportunities needs to be broad because there will be failures. Venture capitalists typically expect that from investment in any 10 new opportunities, five will probably fail, four will be 'so-so' and one is going to be a shining star. Of 100 projects the Government invests in, 10 significant successes will justify all the investment in the other 90.

Invest for success

Industrial Research is confident that we have developed the right business model and processes that will see us deliver significant value for New Zealand. Nurturing and guiding our technology through into market commercialisation by involving ourselves in the deliberate creation of businesses around it, will inevitably be a more reliable method of capturing value than 'throwing it over the fence'.

Not all the businesses will succeed, but with a number of opportunities already in the pipeline – any one of which having the potential to become $500 million plus industry for New Zealand – we feel that the probability of some very significant business successes is high.

We need a diversified portfolio of technology-based businesses, based on the competitive advantage of world-class science, and well supported, strategically developed technology platforms that represent positions of real strength and an innovative mix of skills and disciplines.

And, while it's clear that we have to invest more in the business end of technology development, it should also be clear that we must invest equally strongly in the science end. We will need to constantly feed our profits from business success back into developing and sustaining new and existing areas of world-class and world leading science.

We are in the science business, after all. It almost goes without saying that scientists are the key to this. From world-class science New Zealand can create world-class, economically significant businesses.

The MacDiarmid Institute for Advanced Materials and Nanotechnology

Paul Callaghan
MacDiarmid Institute, Victoria University of Wellington

Background

In 2001 two apparently unrelated, but ultimately connected, events took place. First, Alan MacDiarmid made a nationwide tour, subsequent to his 2000 award of the Nobel Prize in Chemistry, an award shared with Alan Heeger and Hideki Shirakawa for their co-discovery of conducting polymers. Alan greatly raised the enthusiasm of New Zealanders, and in particular the Government and its advisors, for excellence in research in general and excellence in basic science in particular. He further drew attention to the remarkable developments taking place in advanced materials research worldwide. Second, the New Zealand Government announced that it intended to fund a small number of Centres of Research Excellence in New Zealand universities. These Centres were not necessarily to be located in a single place. Indeed, universities were encouraged to consider partnerships which would group together critical masses of excellence in specific fields of research.

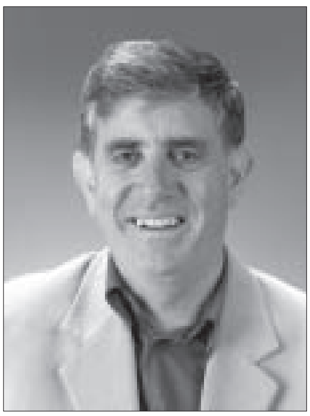
New Zealand has always had a vibrant community working on condensed matter physics and materials chemistry, and it was natural that applications would emerge from this group. In the first round of applications, two very interesting proposals came from teams, led respectively by researchers at Victoria University of Wellington and the University of Canterbury. It became immediately apparent that we would present a far better cluster by amalgamating our proposals. This coordinated bid took the name, The MacDiarmid Institute for Advanced Materials and Nanotechnology. We were successful, being awarded an operating grant of $4.2m per annum over six years, along with a capital start-up grant of around $10m. The operating grant effectively doubled the external income of the group, an income based on Marsden, NERF and other research contracts.

The MacDiarmid Institute is a partnership between Victoria University of Wellington (VUW), the University of Canterbury (UC), Otago University (UO), Massey University (MU), Industrial research Ltd (IRL) and the Institute of Geological and Nuclear Sciences (GNS). It comprises over 30 Principal Investigators (PIs) at 7 Institutions, five universities (the above group, along with the University of Auckland), and the two Crown Research Institutes. Leadership is provided through the Director (Paul Callaghan at VUW) and the Deputy Director (Richard Blaikie at UC), while the Institute is managed by Margaret Brown at VUW and Rebecca Munroe at UC. The research is grouped into four themes: Nanoengineered materials and devices; Novel electronic, electro-optic and superconducting materials; Functional materials; and Soft materials. Details about the research objectives and our PIs can be found on the website www.macdiarmid.ac.nz

Our research themes

The world-wide investment in **nanotechnology** research is aimed at improving existing products and processes, and creating new kinds of materials and devices. The broad objectives of our work are to: (1) develop an understanding of nanofabrication processes and of building elements of nanoscale systems, (2) develop techniques for fabricating new materials and devices with nanoscale dimensions, (3) feed the results of (1) and (2) into engineering projects with clearly defined technological goals; and (4) provide infrastructure which will allow nanofabrication techniques to be applied within New Zealand. Projects build upon the group's strengths in novel low-cost nanofabrication, electronic and optical materials and devices, with expansion into new areas of chemical and biological nanostructured devices. New Centre of Research Excellence (CoRE) funded-activities expand the group's recent successes in the development of evanescent near-field optical lithography, nanoimprint, fabrication of nanodevices from atomic clusters, and understanding of process-induced damage in GaN.

Within the **electronic materials** theme, the mix of programmes is a balance of the mature (amorphous semiconductors and high-T_c superconductivity) and the completely new (light-induced nanoscale glass-ceramic lithography, organic-inorganic oxides). There is strong overlap between themes and sub-themes. The processing and substitutional physics and chemistry of the manganites, ruthenates, cuprates and organic/inorganic oxides are very similar to those of other oxides in the



Paul Callaghan was born in New Zealand and took his first degree in Physics at Victoria University of Wellington, followed by a DPhil degree at Oxford University. He is Alan MacDiarmid professor of Physical Sciences at Victoria University of Wellington and researches the applications of magnetic resonance to the study of soft matter.

Paul has published over 180 articles in scientific journals as well as a book on magnetic resonance. In 2001 he became the 36th New Zealander to be made a Fellow of the Royal Society of London.

functional materials theme, and commonality of methods for fabricating thin films is also shared with the nanotechnology theme. The hybrid organic/inorganic materials are true nanoscale multilayers. Device development should provide much interaction with the nanotechnology programme, while the glass ceramics programme provides a novel form of nanoscale photo-lithography.

A revolution in the design of synthetic structures and intelligent materials capable of intrasystem communication is imminent. These **functional materials** have application in sensing, processing and the storage and transmission of information. Our projects involve the development of nanomaterials and new microstructures in advanced materials for electronic, opto-electronic, sensing, energy capture and storage, engineering and other industry or consumer applications. Manufacturing in the 21st century will feature integrated circuits and composite products composed of molecular devices of nanometer dimensions. New consumer products that exhibit enhanced strength, higher energy efficiency and conversion, specific reactivity and selectivity, durability, biological and environmental compatability, will be increasingly required by society. A number of the PIs have longstanding international collaborations in this field, and have particular expertise in conducting polymers carbon nanotubes, nanofibres, light-harvesting materials, fullerenes, catalysts, ceramics, porous materials, glassy metals, high-quality paper and paint, surface reactive and energy storage materials. Our aim is to advance scientific understanding of these materials, optimise their properties, introduce novel functionality and use them to make high-performance devices, sensors, products and systems.

The **soft materials** theme extends our materials scope to include polymers, liquid crystals and complex molecular assemblies, as well as encompassing fluids in porous media. This research, which is founded in statistical physics but which intersects physics, chemistry and chemical engineering, is particularly relevant to processing technologies and to molecular self-organisation. Nuclear magnetic resonance (NMR) techniques are paramount in this theme, and provide a strong link across the CoRE. The MacDiarmid Institute is major international materials NMR centre.

What are our strengths?

Clearly, the research focus of the Institute concerns Advanced Materials and Nanotechnology. However, we are, in my view, about something much larger than that. Of all the newly established CoREs, we are unusually committed to being a 'distributed centre', an oxymoron if you will, but an idea whose time has come. While Victoria University 'hosts' the Institute in the technical sense that it handles the funds transfers and provides an administration base, it does not dominate the Institute. The Institute is based on a sense of partnership in which the corporate ego of any one university will be secondary. Victoria University or Canterbury University, or Otago or Massey Universities for that matter, can feel proud of us. But we are equally determined that we will draw on the strengths of our CRI partners and, in turn, impact on the way they see their future. In the end we want to build something new, crossing the boundaries of the universities and CRIs in order to build a critical mass out of New Zealand's fragmented and distributed talent.

We start from a solid base. Students undertaking graduate research training within the Institute will join a research culture founded on a proud heritage of excellence. Former graduates from Departments represented within the Institute include two Nobel laureates, Rutherford (UC) and MacDiarmid (VUW), and eleven Fellows of the Royal Society of London: Rutherford (UC), Barrer (UC), Mitchell (UC), White (VUW), Ziman (VUW), Roper (UC), Clark (UC), Axford (UC), Kelly (VUW), Stephenson (VUW), and Callaghan (VUW). Staff within the Institute have many active collaborations with some of the world's leading experts in materials science. These linkages are reflected in the outstanding quality of our International Advisory Board. Our students have access to a remarkable network of distinguished international scientists, including many outstanding New Zealanders working at the highest levels of international achievement. These include Professor Alan MacDiarmid of the University of Pennsylvania, Professor Neil Ashcroft of Cornell University, Professors Mark Warner and Volke Heine of Cambridge University, Dr David Lockwood of the Canadian National Research Council, and Professor Michael Kelly of Surrey University. Many of the PIs of the MacDiarmid Institute have been trained in some of the world's best research environments and most retain strong international contacts. Not only does the MacDiarmid Institute represent a strong link to international science. It also represents a conduit for the expertise and association of some of New Zealand's most distinguished scientific expatriates.

Another interesting aspect of the Institute is its potential to contribute to New Zealand's economic development. In a 2001 issue of the journal, *Advanced Materials*, the Minister of Research, Science and Technology, the Hon P.C. Hodgson, pointed out that "the development of new materials and new technologies in materials science, for application in our local industries, needs to be a fundamental part of our new economy." Examples cited in that article were mostly taken from work currently undertaken within the grouping represented by the MacDiarmid Institute. Three examples serve to illustrate the involvement of Institute investigators in technology implementation and commercialisation. First, the treatment of silicate by-products from geothermal energy production has resulted in the production of new coatings to provide higher print-quality paper. Second, the discovery of a new high temperature superconductor and the development of suitable wire production technology, has resulted in the mass manufacture of high T_c superconductor wire (HTS) by an American Company using New Zealand–owned IP, leading to the installation of the world's first HTS power cable in Detroit. Third, the development of evanescant wave near-field lithography has the potential to produce a new generation of optical elements and opto-electronic devices with New Zealand-owned IP. The research staff in the MacDiarmid Institute have a track record of inventiveness and commercial awareness, and 51 patents are currently held by the PI team members.

CoREs were established in order to enhance the capacity of New Zealand universities to train graduate students in areas where we are strong. Graduate training is a key focus for the MacDiarmid Institute, one of our main aims being to encourage our students to acquire an interdisciplinary perspective. Modern materials science developments involve research at the overlap of disciplines, especially those of chemistry, physics, and engineering. The formation of the MacDiarmid Institute rests on a commitment to interdisciplinary cooperation between these subject areas. The recent establishment of the MacDiarmid Chair in Physical Sciences at VUW is a reflection of the value placed by the host university on teaching and research at the interface between chemistry and physics. The active collaboration between engineering and physics researchers at UC reflects a similar commitment to breaking down discipline barriers. Equally, the VUW, UC and MU groupings have strong links with IRL, GNS, WRONZ and other research organisations, in their training of research students. A large number of undergraduate students in physics and chemistry take summer employment at IRL and other CRIs.

Ongoing professional development will be a key part of the research training provided to research students within the institute. All young researchers, whether honours, Masters, PhD, or postdoctoral fellow, will be expected to contribute to formal and informal seminars on a regular basis (at least twice per year). Every effort will be made to give students the opportunity to work for a period in a different but complementary environment such as a CRI, in industry, or in an overseas laboratory. All PhD students will be given the opportunity to attend at least one overseas conference during the period of their PhD.

The formation of the Institute provides new access to infrastructure. All facilities will be available for use by PIs, research students and postdoctoral fellows within the Institute through mutual collaboration. Capital facilities include molecular beam epitaxy, ultra-high vacuum (UHV) cluster deposition apparatus, plasma etching and electron beam lithography, broad-band laser spectroscopy, transmission and scanning electron microscopy (TEM and SEM), a complete range of NMR systems at fields up to 11.7 T, including solid state NMR, micro-imaging, rheo-NMR, and liquid state high-resolution NMR, stress-controlled rheometry, X-ray diffraction, UV, visible and IR spectroscopy, Raman spectroscopy, variable field magnet facilities, vacuum and cryogenic capabilities, thin-film preparation facilities, photoelectron spectroscopy and sputtering ion mass spectrometry, and a nuclear accelerator with Rutherford backscattering and nuclear reaction analysis capability. As a result of the capital injection, the Institute has new capability in electron beam lithography and mask alignment, in analytical field emission SEM, in TEM, RF/magnetron sputtering, new laser facilities, new NMR gradient facilities, a new Raman spectromter, new rheometers, a SQUID magnetometer, new atomic force microscopes, new gamma ray detectors, a spectrum analyzer, quasielastic light scattering, and ellipsometry.

As part of the formation of the Institute, PIs will gain access to library database and electronic journal facilities by all Institute researchers, thus combining the capability of VUW, UC, UO, MU, and IRL.

The first six months

The first six months of the MacDiarmid Institute have seen a hectic pace of implementation, with most of our focus on the ordering, delivery, and installation of new research equipment, made possible by the capital injection to the CoRE. The operating funding has started to flow and this has resulted in the establishment of new positions, the preparation of advertisements and the selection of appointees. We have established the website, published our first annual report, published a high-quality newsletter (*The Interface*) and implemented a programme of regular Institute-wide seminars, using video link-up, connecting researchers across the country and twice linking with United States colleagues. The Board has been established and has met twice, in Wellington and in Christchurch. The expertise which that Board brings to the Institute from the wider research and business community will be of enormous value to us. We have advertised for new Principal Investigators and Associate Investigators to join us, using an open and competitive process as set out in our original plan. As a result, two new PIs (Yacine Hemar and John Evans) join us this year, each funded at a rate of $40,000 per annum. In February 2003, the International Advisory Board was invited to comment on our productivity so far and provided valuable feedback.

During February 2003, we ran AMN-1, a major international conference in Wellington which launched the Institute in a very public way. The presence of three Nobel laureates, most of our International Advisory Board, and a large number of other distinguished international speakers, gave a prominence to New Zealand materials and nanotechnology research which we have rarely seen in the past. AMN-1 was opened by the Governor-General Dame Silvia Cartwright, and featured a reception at the Grand Hall of Parliament and an evening in which schoolchildren met the Nobel laureates. News media interest was exceptional.

Problems and challenges

In a sense we are still catching our breath at what has happened. As we look at our new equipment, and as we see new faces arriving and joining our effort, we can only feel a sense of optimism for the future. This is a rather unusual feeling in New Zealand research, but it is welcome and it gives us a sense of renewed energy. At the same time the optimism is tempered by some harsh realities. First, the New Zealand university system, within which our Institute operates, is chronically underfunded, especially in science and engineering, and the prognosis for any improvement is poor. As a consequence we are trying to build world-class science and technology on an infrastructure which has been so diminished that it is barely credible. It functions only because of the nearly superhuman efforts of some remarkably talented and committed people. Second, there is a disconnection between the agencies of government that deal with education, and the agencies that deal with RS&T. Whatever the goals of our nation's RS&T strategy, they will fail if they are not comprehended and incorporated by the those who fund and frame policies for both tertiary and secondary education.

Finally, we are all aware that we may train the best researchers in the world, but they may yet take their skills to that world rather than remain to work in New Zealand. We may produce the best ideas and inventions, and yet that IP may end up being exploited by the rest of the world, rather than by us. How do we avoid that? We change the social and economic culture of New Zealand. It's a big task for the MacDiarmid Institute, but we will play our part. We are all in a race against time, a race that can only be won through partnership.

Science for global environmental problems – lessons from Montreal for Kyoto?

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Ministry for the Environment

All opinions and analyses expressed in this paper are solely those of the author and are not necessarily endorsed by any government department or the New Zealand Climate Change Office.

Introduction

The 20th century has seen a growing awareness of the Earth as a finite system with limited resources, and humans impacting on those resources. Addressing global environmental problems, caused by many emitters around the world, hinges on the collaboration and recognition of a common responsibility on the part of all nations to understand and address the problem.

This paper investigates the key elements of the Vienna Convention for the Protection of the Ozone Layer and the Montreal Protocol that led to its overall success and enhanced collaboration across both developed and developing nations. The paper then identifies parallels, but also important differences, between ozone depletion and climate change, and discusses the main lessons from Montreal that could be applied to New Zealand's science system to best inform and support climate change policy under the Kyoto Protocol.

A brief history of the Montreal Protocol

The first warning that human activities could affect the stability of the ozone layer were sounded by Crutzen (1970), followed by Molina & Rowland (1974), who discussed the potential effects of chlorofluorocarbons (CFCs).

Growing concern led to a series of UN-sponsored expert committees that culminated in the signing of the Vienna Convention for the Protection of the Ozone Layer in March 1985. The Convention called for both research and actions to limit anthropogenic damage to the ozone layer, but was non-specific about which gases were most relevant. Most importantly, the Convention did not mandate emission reductions.

In May 1985, Farman et al. (1985) published their observations of the Antarctic ozone hole. This sparked a period of intense polar atmospheric research, with rapidly converging evidence that chlorine gases derived from CFCs were responsible for dramatic seasonal reductions in ozone concentrations over Antarctica and the Arctic.

The Montreal Protocol was signed in 1987, mandating legally binding limits to the production of CFCs for developed countries. Subsequent amendments to the Protocol mandated increasingly rapid phase-out, including full participation by developing countries albeit at a slower pace. At the same time, CFC replacements with reduced (or zero) ozone depletion potential were being developed, largely by the same companies that previously had manufactured CFCs.

Owing to the Montreal Protocol and its subsequent amendments, chlorine levels in the atmosphere are now roughly at their peak, and the peak of ozone depletion is expected during the first decade of the 21st century. A gradual recovery of the ozone layer and disappearance of the ozone hole are expected by about 2050, assuming that no other atmospheric changes (such as climate change – see Shindell et al. 1998) will interfere with this recovery process.

It is notable that, even with this optimistic recovery time, there is a lag of about 30 years from the first discovery of a global environmental risk to the period of maximum environmental damage, and a lag of more than 60 years from the beginning of concerted international action until the environmental perturbation will have been reduced to levels prior to anthropogenic interference (WMO, 1998).

Success elements of the Montreal Protocol

What made the Montreal Protocol successful? I suggest that the following elements were critical to gaining widespread acceptance across both developed and developing countries:

- a grace period for developing countries allowed a gradual approach to phasing out CFCs and adopting new technology;
- a simple ultimate target (namely 'zero' emissions) ensured certainty about global long-term goals and ultimate partici-

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pation by developing countries, which encouraged industrialised nations to lead;

- technology transfer to developing nations through a multilateral fund, in addition to targeted assistance, ensured that the Protocol increased international equity;
- continued revision of phase-out targets was aligned with periodic reviews of the scientific evidence through an international scientific assessment body;
- a dramatic environmental event (the ozone hole) signalled to the public and decision-makers the potential seriousness of the problem;
- development of technological solutions (CFC replacements) brought major companies on board, convinced major industrialised nations such as the USA to sign up to the Protocol, and allowed developing nations with limited financial or technological capacity to participate without jeopardising their own future development.

Parallels with climate change

At first sight, there are striking parallels between the challenges posed by ozone depletion and climate change.

Both issues are environmental problems caused by emission of long-lived gases released as by-products of industrial activity. In both cases, emissions by industrialised nations are responsible for the bulk of emissions to date, and the precautionary principle was employed to encourage early action by industrialised nations to reduce emissions (Pearce, 2001).

There are also many scientific parallels between ozone depletion and climate change. Obviously, both are topics of global atmospheric change and its impact on natural and human systems, and their solution requires research into options to reduce emissions of the culprit gases without compromising standards of living. But there are also other, potentially more interesting, parallels concerning the role of scientific scepticism, uncertainty and inertia.

Scepticism about environmental problems comes in many shades. It ranges from informed caution and caveats by active researchers (which is vital to maintain scientific integrity and to prevent over-reactions), to small groups of very vocal sceptics whose opinions and publications are difficult to reconcile with a purely scientific agenda. Interestingly, today's most persistent and vocal scepticism about climate change is expressed by (almost) the same people, using (almost) the same arguments, as 20 years earlier in the case of ozone depletion. This scepticism ranges from doubts about the very existence and the seriousness of the problem, to doubts over the political and technological feasibility of the proposed solutions.

Discovery of the ozone hole, and subsequent revisions of the chemical mechanisms involved in ozone depletion, highlighted the limited capability of science to forecast the major perturbations of complex Earth systems. The resulting 'surprises' can either reduce or exacerbate the environmental effects originally predicted by the first simplified models. In the case of ozone depletion, much of the scepticism about the necessity to address the problem, or the feasibility of proposed solutions, has proved to be ill-founded in retrospect. It is important to realise that this is not because the sceptics did not understand the science sufficiently well (nobody did in the beginning), but because it was exactly this lack of a complete understanding of the problem that necessitated and justified a precautionary approach, well before all major chemical and dynamic mechanisms were fully understood. It is only because of this precautionary approach that it will take 'only' 80 years from discovery of the potential problem to its eventual resolution.

Scientific uncertainty about future rates of climate change and its impacts, inevitable surprises, and the uncertain feasibility of various solutions, all suggest that a precautionary approach is similarly justified for climate change, including the establishment of an international framework that allows future broadening and tightening of emission targets.

Where climate change differs from ozone

Despite certain parallels, there are key differences between climate change and ozone depletion. I will focus only on those with a scientific or technological aspect.

Most importantly, perhaps, CFCs were specifically manufactured for a limited and clearly defined range of industrial uses, whereas greenhouse gases are ubiquitous by-products of almost every form of energy production and every industrial, agricultural and transport system. It is therefore not easy to invent 'substitutes' for greenhouse gases; their generation is an accident of civilisation rather than part of a specific industrial process. At present, alternatives for the processes that generate greenhouse gases are still limited on a global scale. Hence, a global zero-emissions target for CO_2 is not practicable, even in the long term, and considerable uncertainty about desirable and feasible emission targets remains.

As far as global environmental effects and human costs are concerned, the impacts of climate change are likely to fall disproportionately on developing countries, whereas the impacts of ozone depletion were most threatening to the mid- and high-latitudes where developed countries, or countries with economies in transition, are located.

Finally, the effect of greenhouse gases on the climate system, and the effects of climate change on ecosystems, are scientifically much more complex and cross-disciplinary than ozone layer depletion. Hence, one may expect a significantly larger potential for surprises and non-linearities. In parallel to this greater complexity, the greater inertia of the climate system implies that global impacts will evolve and persist over centuries rather than decades, and essentially be irreversible over many human generations.

Lessons for climate science in New Zealand

Given the parallels and differences that exist between ozone depletion and climate change science, and the political context in which they operate, what lessons might we draw for New Zealand's climate change science policy?

Understanding or solving the problem?

Ratification of the Kyoto Protocol has introduced a new fiscal responsibility for Government, and it is only logical that options for emissions reductions must ascend the ladder of research priorities. At the same time, it is virtually certain that there are surprises in store on how the climate system will respond to a further rise in greenhouse gas concentrations, and what its particular impacts on our region will be. The climate system is too complex, and we are moving too far and too rapidly into uncharted territory, to believe that our ability to model 20th century climate changes guarantees that we know everything we need to know about the climate of the 21st century and beyond.

More importantly, just as the ozone hole had an unpleasant geographic proximity to New Zealand, the Southern Ocean and Antarctica are vital barometers of global climate change, and unexpected modal shifts in this region could have major effects on New Zealand. We cannot rely on other nations' research programmes to undertake studies in this region on our behalf.

The desirable balance between research to reduce emissions, and research to understand and predict future climate change and its impacts, is a vexing problem that cannot be solved on the basis of science alone. Its answer requires value judgements about how to treat short-term versus long-term risks, high-impact/low-probability versus low-impact/high-probability risks, and global and domestic equity considerations.

International negotiations and domestic targets

International negotiations for new emissions targets, and potentially a whole new system to regulate global greenhouse gas emissions, will begin formally in 2005. This means that the science and projections necessary to underpin New Zealand's position in those negotiations will need to come out of *current* research programmes.

Nonetheless, decisions about future emission targets for New Zealand will also rely on value judgements as well as scientific and technological information. Policy-makers and industry therefore need to work together with scientists, including experts in Sustainable Development, to form the necessary intellectual capacity to engage in the decision-making processes about future global action on climate change and New Zealand's position within this framework.

Developing plausible solutions

Just as early action by industry against ozone depletion was limited by the lack of CFC substitutes, reductions in greenhouse gas emissions are hindered by the perception in both developed and developing countries that greenhouse gas emissions are an inevitable by-product of a high standard of living. Turning the Kyoto Protocol from a fiscal liability into a method for achieving sustainable structural change requires solutions that are appropriate to a nation's level of technology, ecosystems and financial and political capacity.

Research on mitigation measures undertaken in New Zealand obviously needs to address our national needs and opportunities, both where we can develop our own unique solutions, and where we can collaborate with other countries in larger research programmes. However to allow emission reductions to become a truly global effort, we also need to investigate solutions that are applicable to developing countries with which we share close cultural, social, economic or technological connections.

There is also a need to better understand the pace and cost of technological change. For a number of reasons, projections of the cost of major technology changes have often turned out to be overestimates (SEI, 1999). Better cost estimates are especially important where systems are expected to change on a large-scale, such as a long-term shift towards hydrogen as energy carrier, to determine optimum levels of government support for both technology development and implementation.

Scepticism and public awareness

Scepticism as a scientific principle of 'diligent caution' is crucial to maintain scientific integrity. It helps avoid scientific hypotheses becoming accepted truths solely through political or media support. However, if sceptics selectively promote half-truths to serve special interests, they can seriously hinder public awareness and private sector engagement in addressing environmental problems. How can a non-expert decide whom to listen to, and whether scepticism is a cautious warning not to overstate an untested theory, or whether it promotes a biased and selective view of science and the world? How can a science funder decide on the value of non-mainstream research?

I suggest that adherence to scientific principles of communication and fact-finding, namely independent international peer-review and in-depth assessments of the evolving literature by large groups of scientists, are the only beacons by which non-experts can be guided. In other words, the more complex an area of research is, the more emphasis must be placed on 'good practice' in the *process* of research and communication of its results, including participation in international collaborations, compared to the actual findings of any particular project.

Reliance on multiple international peer-review is one of the most important cornerstones of assessments such as that undertaken by the Intergovernmental Panel on Climate Change (IPCC, 2001; 2003), but the general public and media generally have a limited understanding of the value of such a process compared to individual expert opinions.

Conclusions

Clearly, lessons from ozone depletion cannot be used as a simple blueprint for climate change science policy. However, this paper has attempted to show that a number of lessons might be learnt. In summary, several recommendations for climate change science can be made:

- Expect surprises and maintain vital research capacity in areas that provide fundamental understanding; this includes continuity of researchers that have experience in interacting with international research bodies.
- Integrate private sector research for solutions early into public funding schemes; the current research consortium on agricultural greenhouse gas emissions is an excellent example of such integration.
- Require research outputs in the form of peer-reviewed international publications; define and insist on 'good practice' in communicating research results.
- Increase public appreciation of the science *process* as well as concrete results.
- Create an early and inclusive discussion on long-term targets and strategies that clearly delineates scientific knowledge, sectoral interests, and national goals; all three components are required for a productive dialog.

The fact that climate change is expected to proceed gradually (until major thresholds are passed), and that the effects of climate change may be less disruptive initially in developed countries with the highest per-capita emissions, have clearly been counterproductive to early action in some countries. It can only be hoped that there is one lesson that climate change will not copy from ozone depletion, which is to wait for rapid and catastrophic change in the global system before global action occurs. The inertia of the climate system, and the high likelihood that inhabited areas will be affected, means that any climatic change comparable to the ozone hole could be far more disruptive and become virtually irreversible over many human generations.

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Motu: Excellence in economic research and the challenges of 'human dimensions' research

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Economics as a 'trade' does very well in New Zealand. Economists are taken relatively seriously in government policy processes. For better or worse, economic ideas were major drivers of the reforms in the late 1980s and early 1990s. Plenty of well-paid job opportunities exist in the private sector and in government, and large numbers of economics undergraduates mean that economics departments in Universities are not under threat.

Economics as a science doesn't necessarily do so well. This article discusses some of the opportunities and challenges ahead in creating a vibrant economic research community in New Zealand that can usefully contribute to public policy. We bring particular attention to the challenges of producing good interdisciplinary work. Nearly all policy problems are multifaceted and cannot be understood using insights from one discipline alone. Motu is a non-profit research institute that has been set up specifically to address these challenges. At the end of the article we outline our vision of how we are becoming part of the solution and give some suggestions for how both government and researchers could facilitate our and others' efforts.

Why do public policy-related economic research?

Public decisions on issues relating to the allocation of resources are made every day – understanding how individuals, firms, governments and other organisations make decisions about their allocation is the meat of economics. Economics is both a positive and normative science. Its ability to explain a portion of human behaviour, and the internal consistency of its theoretical basis, make it useful for predicting qualitative and sometimes quantitative responses to different policy options. Of course, economic motivations are only a small part of the story. Many other social science disciplines, including political science, psychology, sociology, demography and geography are needed to understand human behaviour. All of these fields face the same difficulties as economics in separating opinion and advocacy from science when considering the outputs of research. Economists often tell a more theoretically consistent and empirically backed story and so can have more credibility in policy debates. Despite the many jokes about economists who disagree, there is actually a very high level of agreement among economists on microeconomics, which is the basis of most public policy analysis. This does not make economists 'right' but it can make them useful.

If economics is going to have policy influence it is important that it is soundly based. Research needs to focus on areas where we can make real progress on issues of public concern. Of course, there are issues that are important but to which economics has little to contribute. Some economic questions are unanswerable however much research is put into them because the natural experiments needed to test them simply do not exist. For ethical (and financial) reasons economists often cannot perform controlled experiments, so that our research agendas are often guided by the possible as much as the important.

That said, research is a waste of time if it does not address issues of concern and is not communicated to those who can use it. End users need to be involved in framing questions and research results need to be explained to them so that they understand their implications and limitations. This does not imply 'participatory research'. Ideally, we want our subjects to be unaware that they are being studied to avoid influencing their behaviour.

Opportunities and challenges for policy-related economic research in New Zealand

New Zealand has many advantages for economic research on public policy issues. Since the mid 1980s, both policy makers and the public at large have been very open to economic ideas and to fundamental analysis of public institutions. Economists have had significant influence on policy and institutional design. In addition, we have been through a period of major change, driven by both internal and international pressures. One result of all of this is that many interesting policies can be studied. Some, such as the fisheries Individual Transferable Quota system, have been designed pretty much according to the textbook approach. This allows us to research and test the effectiveness of these policies empirically. Such research is of international interest and sometimes attracts international funding.

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In addition, because we are such a small country, we have relatively complete and detailed geographic datasets covering many issues, whereas in larger countries these data are often collected at a regional level or some higher level of aggregation. As a small country, we cannot influence international prices, and therefore regard international changes as exogenous shocks that can be the basis of economic 'natural experiments'. Finally, and as in other fields, both the interest of our economic policies and the attractiveness of our country makes it relatively easy to attract foreign visitors to alleviate our intellectual isolation.

Some of the problems faced by economic researchers in New Zealand will be familiar to all researchers. Isolation from international debate, high teaching loads in Universities, and difficulties in buying out time for research, are common issues. In some ways economic researchers are different. Economists do not require large amounts of expensive equipment. We tend to work in groups of at most three, and often alone. We do not need to undertake expensive fieldwork. When we do empirical work, most of our raw data comes from existing Statistics New Zealand surveys or administrative databases (e.g. data on fisheries management or unemployment beneficiaries). Rather than working on one large multi-year project with a single major outcome, we tend to do many related pieces of work in order to gain insight on a problem from different perspectives.

These are some of the reasons why economists do not have, and possibly do not need, a CRI of their own. However, the decentralised approach to research creates needs of its own. Although we rarely collect our own original data, we do need considerable resources to clean up and organise the datasets that others collect so that they become useful for our purposes. Where there are issues with data confidentiality it can be a considerable investment to find secure ways to allow the data to be used. No single researcher can do these tasks alone. If data development is not co-ordinated and supported, it will advance only slowly, if at all. When new surveys are required to meet research programmes, we need to co-ordinate our advocacy for those surveys and provide input so they are designed optimally for economic research. In contrast to statisticians' requirements for surveys (excellent estimates of a few key variables), economists seek datasets that address a range of research questions, demanding consistency across time and in variable definitions across surveys. A key problem for all social researchers in New Zealand is the shortage of longitudinal research datasets where you can track the same person over a number of years.

Another problem that arises from institutional and geographic dispersion is simply that of communication. Many researchers simply do not know about related research by others in New Zealand. A competitive attitude in some universities makes this even worse. Some researchers are not making work available until it is published (often a 1-2 year lag). Worse, much research remains unpublished because it is perceived to have commercial value or political sensitivity. Even where it is made public, the lack of effective networks often means that research is not widely known. The New Zealand Association of Economists provides useful services here, but there is no obvious central point for finding out about research. CRIs provide some of this service in other applied fields.

For an 'economist' the value of economics in government and commercial uses means that lucrative consulting is available. For 'economics' this can be a problem. It is harder to attract good people into research and more expensive to pay researchers. Many of the most highly trained economists in New Zealand work in government or consulting. Some try to do research within those constraints but they are always under pressure to provide short term policy or commercial advice. Quite a lot of funding is available from government departments for economic research but such research tends to be short term and ask very large questions that cannot realistically be addressed within the time and funding scales provided, if at all. The contracting and consultation costs involved in each project often overwhelm the actual research costs. Researchers tend to become generalists rather than specialists because they cannot predict a long-term commitment to an area of research and therefore don't invest in their knowledge. This type of funding usually leads researchers to produce consulting reports rather than true research. While consulting reports serve as a valuable and important input into the policy process, they are not a substitute for long-term research investment. Furthermore, the quality of consulting reports can be greatly enhanced if they are able to draw on an established body of evidence and thinking built up through past research. Short term funding, even if repeated, also reduces incentives to find solutions to the longer-term co-ordination and database building issues.

Anyone with an undergraduate degree in economics can call themselves an economist. Some of these people are very smart and well trained, but others are not. To an outsider it is difficult to distinguish between those who have high level research capabilities in economics and those who are simply capable economic practitioners. Much New Zealand economic/public policy research resides in the grey literature where quality is difficult to judge. Poor quality research is often of no value because it involves conceptual ideas that might be misapplied or misinterpretation of existing data. Such research can be dangerous because end users might not recognise the problems. It is also hard to draw the line between 'research' that involves advocacy and scientific economic research. Both have their place but they should not be confused. The political salience of most of the issues with which public policy economists contend makes this distinction more difficult than in many scientific fields (obvious exceptions are the GM debate or the climate change debate). This makes peer review and close attention to the quality of the research process even more important.

Motu: Economic and Public Policy Research Trust

Motu is a Charitable Trust dedicated to public policy and economic research. Motu has three basic goals: excellence, objectivity and dissemination. We seek to carry out our own excellent research and to provide some of the missing infrastructure to help make other researchers more productive. Primarily we carry out long-term research and place a strong emphasis on building research databases and on linking our work with that of other New Zealand researchers through an affiliate programme, subcontracting and workshops. We work to recruit excellent New Zealand economists by providing a stimulating environment with good resources and few bureaucratic demands so that they can focus on what they do best.

We believe strongly that a healthy democracy needs access to high quality objective (or at least disinterested) research on key policy issues. We choose research topics that we believe will provide insight into long-standing policy problems, rather than merely responding to specific short-term needs. We are careful to separate our research findings from our interpretation of those findings for policy purposes. We often distance ourselves from consulting which brings the attendant risks of pressures to meet client desires or hush up research with unwelcome findings.

We do some consulting work because we find that an effective way to disseminate the results of our research and learning, or as a means of funding worthwhile research projects on topics where our own areas of interest and expertise overlap with those of 'clients'. The gap between academic research and its application to specific problems is considerable and so we try to bridge that gap where possible. All of our work is made public, and we try to present it both verbally and in writing in ways that are accessible to lay people and policy analysts as well as to meet the demands of academic audiences. We see ourselves as responsible not only for disseminating our specific results, but also for raising the level of debate on issues of interest to us more generally. Both to introduce new ideas and to strengthen the research community, we encourage and facilitate foreign visitors in our areas of expertise.

We are now in our third year as a charitable trust. Currently we have major work programmes on 'Adjustment and Inequality', 'Land use, climate change and Kyoto', fisheries management, and 'Is New Zealand an economic state of Australasia?' The positive response of academics, policy makers and funders to our efforts has been extremely gratifying. It makes us believe that the will and talent needed for effective synergistic research is there and simply needs careful fostering.

'Human dimensions' research – the interdisciplinary challenge

Public policy issues that relate to the natural sciences are inherently multifaceted and their resolution requires a multidisciplinary approach. This creates additional challenges. Motu is trying to bring human dimensions more effectively into the analysis of certain science-based issues. We have some experience in this area from a multidisciplinary, multinational, multiyear project on deforestation in Costa Rica. We are trying to apply the lessons from that project and learn more in our FRST-funded project on land use, climate change and Kyoto.

We have found a high level of enthusiasm and co-operation for this project in New Zealand, which is most gratifying. People do want to address the policy issues and are open to how economics can complement New Zealand's considerable natural science expertise. However, it is easy to underestimate the difficulties in a process of this type. Different disciplines are like different cultures and, without an awareness of our own cultural biases and habits, misunderstandings can become sources of offence or misdirection of effort. We must be ever vigilant. The other key risk is 'fluffiness'. A project that tries to do everything across many fields risks doing nothing well. Many 'interdisciplinary' projects are simply collections of disparate parts where the whole is no greater than the sum. Others end up with low quality input from some or all of the relevant disciplines. So far we have found that the keys to success are choosing the right people, defining their roles appropriately and fostering a team environment that ensures genuine, constructive interaction. We haven't got this completely sussed – any suggestions welcome!

Choosing whom to work with is key but also hard. In our first project we went blithely in search of a 'biologist' to provide us with input on carbon sequestration. Luckily we met some excellent people who helped us understand that we needed both field ecologists specialising in carbon measurement and ecological process modellers. Similarly, people often seem to seek an 'economist' or, even worse, a 'social scientist' when there are many different social sciences with very different strengths and few similarities in methodology. Even within economics, there are many specialisations, a problem even when you know the exact skill set you seek. It is hard to assess the quality of a researcher in a field you do not understand. In New Zealand this is sometimes exacerbated because peoples' CVs are either unavailable or uninformative about people's academic experience and credentials (e.g. what publications they have produced and, not only whether the person has a PhD, but in which specialisation and from which university). We now try to find a few excellent people in the field and cross check reputations and suggestions with several people to find a consensus. Clearly, personality and commitment matters too.

One curious and frustrating aspect of being asked to engage in interdisciplinary work is that often the role to which you are assigned is predefined. This might work if defined by an expert in your field, but often it is based on what other researchers understand of your field. For example, economists are often asked to contribute cost-benefit analyses when they might add much greater value in other ways. I'm sure that this applies in the other direction, so we try to be open in the evolution of the project to allow people to define their roles as their understanding of the overall goals of the project deepen. This makes project planning difficult but generates a fertile creative environment that can produce surprising and valuable results.

We have concluded that one of the best ways to foster true communication among disciplines is to construct an empirical model jointly. These models have value on their own but they also force concrete discussions and maintain focus on joint goals. The improved understanding of how components interact within the model that is gained from the painstaking process of building and testing it may be as useful as the specific outputs. It is much easier to build a model by playing the role of expert in others' fields and choosing parameters or data from the literature. Working with people until they fully understand what you are trying to do and you understand what they can contribute, and then having them produce material that allows you to integrate their knowledge into the model, is a slow process. Luckily it is also personally rewarding. We get to work with experts passionate about their areas of research and learn fascinating new conceptual ideas and facts, and there is no exam at the end! The quality of the outputs and the commitment of key experts to the results justifies the effort.

How could economic research on public policy issues be made more productive?

Motu and others are doing their best, but economic research on public policy issues in New Zealand is still under-performing. Here are some suggestions on how we could improve. They apply to both economic and interdisciplinary 'human dimensions' research. Some of these efforts are underway and should be applauded and enhanced. Others are weak and need to be encouraged.

1. The quality of research should be a prerequisite for funding.

Once that is established, other criteria such as choice of topic, method of outreach, effects on capacity etc. should be considered. Much-publicised bad research, even on good topics, is certainly useless and possibly dangerous.

2. More funding needs to be long term.

Long-term funding allows databases to be built and people to develop expertise. This could then be complemented by shorter-term, more focused, research on specific policy needs. Often what policy makers need in the short term is not fundamental research but interpretation of existing research. This would be more effective with a solid long-term research base. More funding is also always welcome.

Government departments need to avoid asking researchers to answer impossible questions. If policy-makers want to have a stock of research knowledge to draw on when they are faced with difficult choices, they need to provide funding on time scales and through processes that allow high quality, carefully planned, research. Someone will always volunteer to answer their impossible questions but the outputs may of necessity be based more on the judgements of the answerer than on any basis in fact. Short-term gain through visible outputs and rapid spending of residual resources before the end of the financial year is surely outweighed by the longer term undermining of research capacity and genuine policy debate.

3. Researchers should be encouraged to seek peer review for their work.

The peer review process is slow and flawed but there is no alternative quality control process. Policy input based on peer-reviewed research findings and from researchers with a history of peer-reviewed research should be taken more seriously than other research input.

4. The balance between talking about research findings and doing research needs to be adjusted.

Currently, there are many meetings and conferences where researchers speak on public policy issues, but few researcher workshops focused on research methodology rather than policy implications. Many government departments require such frequent feedback, even early in a project, that reporting on research takes precedence over actually doing it. Focus on end users is most valuable when there is good research to be used. More time and resources aimed at ensuring the quality of research, and less resource-intensive and more carefully thought out dissemination processes, might create a better balance.

The choice of research questions needs to be made in conversation with end-users but, once the questions are chosen, dissemination of research outputs should not happen until research has progressed significantly. Researchers need space to work effectively.

5. Databases and database access needs to be improved

Relatively little empirical research is done in New Zealand despite the great potential. Statistics New Zealand is addressing this to a certain extent through a range of projects to make their databases more useful (e.g. geographically specific) and more accessible (improved access to unit record data). It is also working with other departments to link databases. The new longitudinal database (SOFIE) will be a valuable research tool. Statistics New Zealand is constrained by complex issues regarding confidentiality but is finding constructive and responsible ways to protect confidentiality while also allowing the data to be used to enhance policy debates. We applaud and encourage its ongoing efforts! Long-term funding for projects that have specific data-building and sharing components, and networks among researchers that encourage use and development of common databases, will also help.

6. Economic researchers need to communicate more among themselves.

Individual researchers can contribute by making more effort to make their research visible to other researchers by publishing their work in progress in web-accessible working paper series. They can also provide clear information on their expertise and areas of active research interest so that other researchers can find potential collaborators more easily and comment on and build upon existing research. This could be facilitated by the creation of common web pages in specific research areas with links to relevant research and researchers and through small, focused workshops to build closer, more trusting working relationships.

7. Good research has to be valued and used.

Once the good quality research is produced, policy makers need to use it actively and intelligently. Researchers need to reciprocate by alerting key people to their findings and offering their knowledge to explore with analysts who have specialised skills in practical policy design, the implications for current policy issues.

If high-quality research is produced it will provide more constructive policy guidance, it should be less controversial and hence more readily accepted, and it will be unnecessary to duplicate it. Future research can move forward from a firm basis.

New Zealand Association of Scientists 2002 Awards

The Association's awards were presented at two events in 2002. The presentation of the Shorland Medal was made at a ceremony in Wellington on 30 October. The other awards, which were won by South Island scientists, were presented at a ceremony jointly organised by the Association and Lincoln University on 7 November. The Lincoln event was attended by about 60 members of the local scientific and academic community, including a number of Association members from the Canterbury region.

Marsden Medal

The New Zealand Association of Scientists' Marsden Medal is awarded for a life-time of outstanding service to science in New Zealand, in recognition of services rendered to the cause or profession of science in the widest connotation of the phrase.

Dr Howard Wearing, HortResearch, was awarded the 2002 Marsden Medal for his outstanding service to entomology and horticultural science in the service of industry.

Dr Wearing has made a large contribution to New Zealand society, and especially to the horticulture industry, since the 1960s. His personal drive and vision for developing multi-skilled research teams to tackle large and difficult problems has resulted in a range of success stories of international importance.

One of his most significant career achievements was to gain access to Japan for cherries and other fruit. This entailed an effective blend of science leadership and country-to-country negotiations over 11 years. Six DSIR Divisions were involved in this project.

Dr Wearing's recent leadership in the area of organic and sustainable production systems for apples has had an immense influence. His scientific integrity and rigour has added significantly to the quality of work on this subject. His programme 'Biological Orchard Production Systems', which ran from 1992 to 2000, has seen the first exports of organic apples from New Zealand – yet another innovation with an important future.

His science leadership has been sustained over a wide range of projects throughout his career. He organised New Zealand's first OECD conference in 1994 on the 'Ecological Implications of Transgenic Plants', a subject that has become highly topical recently. His strong interest in Integrated Pest Management and the reduction of pesticides usage led to a role as co-organiser of an international workshop on the subject in 1982.

His leadership skills were recognised by DSIR through his elevation to Deputy Director of DSIR Entomology Division. His quiet, modest, but strong leadership style successfully recruited many young scientists to the team, spread over a number of locations around New Zealand. This legacy is evident from the substantial contributions that HortResearch entomologists have made to both basic and applied areas of science. His interest in management training of scientists was ahead of its time and has ensured the best possible return on government investment in science.

Dr Wearing is the author of more than 100 scientific publications and 40 other articles, and he has supervised and examined an impressive range of MSc and PhD projects for various New Zealand Universities. His lifetime of outstanding service to science in New Zealand makes him a worthy candidate for the prestigious Marsden Medal.

Shorland Medal

The Shorland Medal, named in memory or Dr Brian Shorland, is awarded for the significance and originality of a personal, life-time contribution to basic or applied research in New Zealand.

Dr Hugh Bibby, of the Institute of Geological and Nuclear Sciences, Wellington, was awarded the 2002 Shorland Medal in recognition of an outstanding personal lifetime contribution to the theory and application of electrical geophysical methods for the exploration of geothermal and volcanic systems in New Zealand, and for devising analytical methods for determining earth deformation parameters from geodetic survey data.

His work has improved the recognition of hot-water reservoirs within the geothermal fields and in the selection of sites for production drill holes by being able to predict the likelihood that a hole would encounter hot thermal conditions. A major highlight was the discovery that the Mokai geothermal field was a major resource, whereas previously it was thought to be a very minor resource.

Some of Dr Bibby's methods have been widely adopted around the world, and his expertise has been called upon to assess geothermal systems in many countries. He has been on missions for the UN to El Salvador, Panama, Honduras and Guatemala and for the NZ Government to the Philippines.

Dr Bibby currently leads a multi-skilled research team that investigates the fundamentals of volcanism and geothermal heat origin within the Taupo Volcanic Zone. The team studies the physical processes of heat transfer, whether or not the system is in a 'steady state', and factors that make magma unstable leading to an eruption. This work has won international acclaim.

Dr Bibby's work is characterised by an outstanding ability in the application of geophysics and a flair for leading large-scale field projects that yield internationally significant results.

All this work has resulted in a number of awards. Dr Bibby is a Fellow of the Royal Society of New Zealand. He was awarded the NZ Geophysics prize in 1978 for his mathematical geodetic theory, and again in 1999, together with Grant Caldwell, for his work in electrical prospecting theory.

Research Medal

The Research Medal is awarded to young scientists for outstanding fundamental or applied research in the physical, natural or social sciences, published during the year of the award or the preceding three calendar years.

The 2002 award was made to Dr Jack Heinemann of the Department of Plant and Microbial Sciences at the University of Canterbury, for his outstanding contribution to the knowledge of horizontal gene transfer in bacteria and the biology of genetic elements outside chromosomes.

His work contributes to the definition of the mechanisms and extent of transfer of genes among micro-organisms in different environments. He and a colleague demonstrated recently that a process of natural DNA transfer that occurs between closely related bacteria is also effective in transferring genes to organisms of different biological kingdoms.

Dr Heinemann has also demonstrated that bacteria can evade antibiotics, and acquire genes for resistance to antibiotics, by invading human cells and exchanging genes with one another while inside the human cells. This paper and related papers have attracted immense international interest.

He has been the primary supervisor to about 10 PhD students and twice as many MSc and BSc (Honours) students, many of whom are pursuing outstanding careers of their own.

For his work, Dr Heinemann has received a number of awards and has been invited to prepare reviews for prestigious journals. He received the American Society for Microbiology ICAAC Young Investigator Award at a very young age. As a Rockefeller Scholar in New York during 2001 he was supported by the Nobel laureate, Joshua Lederberg. In April 2002, the American Society for Microbiology called one of his recent publications the "best paper in the world".

At the age of 39, Dr Heinemann has established himself as a highly productive and accomplished New Zealand researcher. His work may eventually yield insights into the design of fundamentally different anti-infective agents for the control of antibiotic resistance and infectious diseases. In addition, his work is relevant to the volatile debate on assessing the risks of genetically modified organisms to the environment.

Dr Heinemann was awarded the New Zealand Association of Scientists Research Medal in recognition of his innovative and dedicated research.

Science Communicator Award

The Association's Science Communicator Award is given each year for excellence in communicating any area of science or technology to the general public.

This year all nominees for the award demonstrated impressive records of communication in print, radio and to a wide variety of audiences. They had all contributed greatly to the public understanding of science and the collective reputation of scientists and the institutions they work for. Some were especially active in getting information across to stakeholders through industry presentations and publications. In all cases, the nominations provided comprehensive evidence of the nominee's work and energy, and reflected the enthusiasm and pride of their colleagues and their institutions.

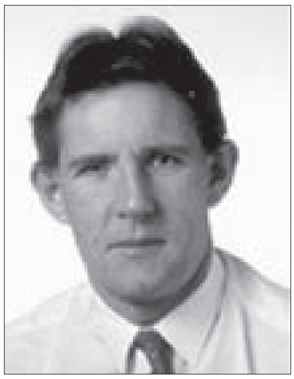
In judging the entries, weight was given to communications that were deemed to be outside the immediate responsibilities of the job - activities that were above and beyond the call of duty - and for activity initiated by the nominee, rather than by the media or communications professionals.

The 2002 Science Communicator Award was won by Dr Jonathan Hickford, of Lincoln University. Dr Hickford is a senior lecturer in Biochemistry, with professional interests in gene sequencing, genetic typing and modification, gene transfer technology, and recombination.

Dr Hickford has made an outstanding and sustained contribution to the communication of science over the past seven years. He is an excellent speaker who can pitch his information to the level and interests of different audiences – from school children to industry groups. In 1999, he was invited to be guest speaker at no less than eleven industry-related meetings. His involvement with schoolchildren is particularly noteworthy.

He has generated an impressive number of articles in the daily press and various periodicals. He has a real gift for putting things in clear, direct and helpful ways. For example, in reference to the use of genetic engineering by New Zealand, he said, "These technologies can deliver good things and bad things; our job is to discover the good" or "In my own instance, these technologies have underpinned the development of genetic tests for foot-rot resistance in sheep". Jonathan is an advocate for the use of those gene technologies he believes to be beneficial, but he shows respect for public intelligence by providing them with sound and complete information to back his opinions.

Dr Hickford's communications efforts, which have gone far beyond the responsibilities of his position, were recently recognised by the Royal Society of New Zealand Council, which has made him a Companion, an honour shared by only 11 other scientists.



New Zealand Association of Scientists 61st Annual Report

President's Report for 2001/02

The New Zealand Association of Scientists began life in 1940 as the New Zealand Association of Scientific Workers, and began publication of its journal, the *New Zealand Science Review*, in 1942. For 61 years NZAS has existed to promote science and benefit society through the application of science, to debate science policy and influence government, and to increase public awareness of science and encourage excellence.

The 2001/02 year has been an active one for Council, with a number of important issues to be dealt with, including *NZ Science Review*, the NZAS Awards, the budget and the ongoing saga on GM which dominated much of this year's election.

Council meetings

Council met eight times at Science House during the year. I would like to take this opportunity to thank members most sincerely for their attendance at meetings, and other communicating members who gave their time to progress the goals of the Association and comment on issues at hand. NZAS Council enjoys a large membership of about 20 persons to represent its membership of about 300, and Council meetings frequently stretch the facilities available in the meeting rooms of the Royal Society. I would particularly like to thank our very active immediate Past President, Janet Grieve, who has kept me on my toes and shared the workload during the year. Together with Ken Aldous in Christchurch, Janet took responsibility for the Awards and organized a number of membership recruitment drives. Despite health problems, Louise Ryan kept our finances in order and continued to take responsibility for membership, our mailbox and the distribution of Science Review. Thanks also to Paul Davis for serving as minutes secretary and Fiona McDonald for circulating the minutes and keeping Council members informed about upcoming events.

NZ Science Review

Under its new Editor, Allen Petrey, supported by the production editor, Margaret McDonald, *NZ Science Review* has continued to provide a forum for science policy issues and science progress in New Zealand. The now familiar silver and black cover format has proved to be very visible and popular, and the journal is favourably received by members and others that peruse its contents. The final issue for 2001 published Jack Sommer's Survey of Scientists entitled 'New Zealand Science Policy Reforms: Voices from the Grassroots', and several associated commentaries. This survey, initiated by NZAS in 1994, was followed up by Jack Sommer in 1996 and in 2000 with Fulbright support. Planning for the next survey needs to be progressed if we are to reap the benefits of scientists' viewpoints on changing science policy. Three issues of *NZ Science Review* will be published in 2002, the first featuring a superb article on biodiversity by Lord Robert May of Oxford, President of the Royal Society of London. A second article by Lord May concerning science in society will appear in the next issue, while the final double issue for 2002 will feature theoretical and mathematical sciences.

The costs of producing *NZ Science Review* now exceed budget, and the incoming Council will need to address this issue to ensure financial viability through the Science Review Trust, which still requires a breath of life.

Awards and Medals

This year the NZAS Awards continued in a revised form after FRST withdrew its financial support and negotiations failed to obtain support from the Association of Crown Research Institutes. As a consequence, and because science journalism is now recognised in other ways, the NZAS Science Journalism Award was discontinued this year. It is worth noting that NZAS has supported this award since 1980, the last few years with the aid of sponsorship. The Science Communicator Award, the Marsden Medal, the Shorland Medal and the Research Medal were continued as normal, and each drew a large number of nominations that kept the reviewers busy. The organisers wish to thank the judges for the considerable time and effort put into careful assessment of the entries. This year, Awards ceremonies will be held in Wellington and at Lincoln University, venues that reflect the recipients' locations. Publicity is being arranged by the respective convenors.

Membership

During the 2001/02 year, membership dropped slightly from 316 to 295, despite a concerted effort to recruit new members, This is disappointing, but is a direct result of a membership purge of all those who have membership dues in arrears by more than two years, despite repeated reminders. In addition, an ageing membership has resulted in a number of retirements, and special issues such as GE have taken a small toll. This coming year, Janet Grieve will initiate further membership campaigns in targeted areas with the hope of increasing awareness of NZAS issues and membership.

Finances

Production costs of *NZ Science Review* continue to dominate NZAS finances, and expenditure on *NZ Science Review* exceeds overall NZAS income. This position is not sustainable. A 20–30% increase in membership fees may have lessened the escalating problem but a significant financial downside remains, and this has been spelled out clearly in the Auditor's Report.

Council activities

Genetic Modification. Recommendations in the Report of the Royal Commission on Genetic Modification received the support of NZAS Council. Legislation imposing a constraint period on commercialisation of GMOs until Sep 2003 was enacted, and discussions have been proceeding on the nature of proposed changes to the HSNO Act to better facilitate low-risk GM research, to allow for conditional release, and to address liability and other issues.

During the year, NZAS supported two nominations to the Bioethics Council, a body being set up by Government following a recommendation by the Royal Commission. Although the Chair of the Council, Sir Paul Reeves, was announced earlier this year, the membership of the Council has yet to be decided.

The Budget. NZAS was supportive of the increased Budget allocation to science this year, particularly the additional commitment to the Marsden Fund and to NERF.

The Election. This year, science issues dominated the early election, providing an opportunity for NZAS to address public concerns, especially concerning GM, which became a political football that influenced the final outcome of the election.

Laboratory News *and the media.* NZAS continued to provide a bi-monthly column for *Laboratory News* this year, with a range of topical articles being published, including commentaries on Government's response to the Royal Commission, NZAS Awards, Lord Robert May's Advice to Government on Science and Social responsibility, Public Awareness of Science, the Science behind Corngate, and Strategic Directions in Science. In addition, NZAS frequently provided comment to the media on science issues in the public domain, and on several occasions has appeared on national TV and radio, particularly concerning the GE issue.

Mike Berridge, President
25 October 2002

New Zealand Association of Scientists (Inc.)

Statement of financial performance for the year ended 31 July 2002

	2002	2001
Income was derived from:		
Subscriptions received	12,890	10,224
Interest received	121	924
Donations	136	2
Dividends - Brierley Invest. Ltd	0	0
Awards Grants	3,650	2,000
	$16,797	$13,150
From which **Expenses** were deducted:		
Accountancy and Audit	450	450
Councillors' expenses	60	581
Depreciation on printer	32	40
AGM and Conference expenses	149	432
Postbox rent	125	125
Postage and stationery	286	316
Royal Society affiliation	618	563
Awards and costs	4,519	2,420
Memorial donation	0	200
	$6,239	$5,127
Excess Income over Expenditure	10,558	8,023
Appropriation – Subsidy for *NZ Science Review*	16,785	17,996
Surplus/(Deficit) for the year:	($6,227)	($9,973)

New Zealand Science Review

	2002	2001
Expenses of production and administration:		
Accountancy and Audit	56	56
Printing and distribution	19,455	20,547
	$19,511	$20,603
Expenses recovered from:		
Library subscriptions and other revenue	2,726	2,607
Subsidy	16,785	17,996
	$19,511	$20,603

Silver Jubilee Trust Fund

	2002	2001
Balance 1 August 2000	15,788	14,840
Interest received	731	948
Balance 31 July 2001	$16,510	$15,788

Statement of financial position as at 31 July 2002

Accumulated funds

	2002	2001
General funds		
Balance 1 August 2001	12,686	22,659
less Deficit for the year	6,227	9,973
	6,459	12,686
Investment reserve		
Accumulated net increase in value of Brierley Shares	342	91
Silver Jubilee Trust Fund		
As per Schedule	16,519	15,788
	$23,320	$28,865

Represented by:

Current assets		
Bank of New Zealand Current Account	3,707	4,615
Subscriptions in arrears	2,340	1,990
	6,047	6,605
less Current liabilities		
Accounts payable	0	563
Subscriptions in advance	50	370
Graeme Coote Fund Donations	414	414
	464	1,347
	5,583	5,258
Investments		
BNZ Deposits	0	6,356
BNZ (Silver Jubilee Trust Fund)	16,519	15,788
Brierley Investments, 1,236 shares @ $0.61	758	803
	17,273	22,947
Fixed assets		
Printer – cost	1,639	1,639
less depreciation to date	1,511	1 ,479
	128	160
Stock of medals at cost	336	500
	$23,320	$28,865

Auditor's report to members

I have obtained all the information and explanations I have required.

In my opinion:
- The financial report complies with generally accepted accounting practices;
- Gives a true and fair view of the financial position of the New Zealand Association of Scientists (Inc) as at 31 July 2002 and the results of its operations for the year ended on that date.

My audit was completed on 30 September 2002 and my unqualified opinion is expressed at that date.

Peter Willis, CA, ACIS
Chartered Accountant, Lower Hutt

New Zealand Association of Scientists

2003 Awards

Nominations are invited for the following medals and awards, offered annually by the New Zealand Association of Scientists.

Marsden Medal

The Marsden Medal is awarded for a lifetime of outstanding service to science in New Zealand, in recognition of service rendered to the cause or profession of science in the widest connotation of the phrase.

Shorland Medal

The Shorland Medal is awarded in recognition of a person's major contribution to basic or applied research that has added significantly to scientific understanding, or resulted in significant benefits to society.

Research Medal

The Research Medal is awarded for outstanding fundamental or applied research in the physical, natural or social sciences published during the year of the award or in the preceding three calendar years. Nominees must be under the age of 40 on 1 January of the year in which they are nominated except that, where a scientist has had an interrupted career, the age limit may be extended to a maximum of 45.

Nominations for each of the medals should be accompanied by a **curriculum vitae and a citation, signed by one or more sponsors**. The citation should be written in a style suitable for the judges and the general public, and should explain the significance of the nominee's contribution.

Science Communicator Award

One or more awards will be made to practicing scientists for excellence in communicating science to the general public in any area of science or technology. Nominations are sought from science organisations, scientific associations and individuals. We seek to recognise a sustained, consistent record of excellent public communication in print, broadcast, public lectures or exhibitions, or through the organisation, management and promotion of events that communicate and publicise science.

Nominations for the Science Communicator Awards should be accompanied by a citation signed by one or more sponsors, in a style suitable for the judges and the general public that explains the nature and extent of the nominee's contribution to excellent science communication.

Note: NZAS has discontinued awards to journalists and freelance writers and monetary prizes.

All nominations should be forwarded to:

The Secretary,
New Zealand Association of Scientists,
PO Box 1874, WELLINGTON

Postmark deadline: 31 August 2003

New Zealand Association of Scientists

Registration Form

I wish to become a member of the New Zealand Association of Scientists.

Applications must enclose payment to be complete. Please photocopy this form and return to:

Membership Secretary
New Zealand Association of Scientists
P O Box 1874
Wellington

Name ....

Preferred title ....

Position ....

Mailing address (work address preferred) ....

....

....

Telephone ....

Fascimile ....

E-mail ....

Membership Fees:

- Individual - $55.00
- Joint members - $65.00
- Student/unwaged/retired - $35.00
- Corporate - $105.00

Subscriptions to *NZ Science Review* only:

- High school libraries - $55.00
- Libraries (other) - $65.00
- Individuals - $55.00
- Overseas postage - $15.00