Impact of the New Zealand Science System 2010

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1.1 This report identifies the impacts of the New Zealand science system, and the inputs and outputs that lead to these impacts.

1.2 As a policy advice agency, the Ministry of Research, Science and Technology (MoRST) has a particular interest in the impact of the science system on New Zealand's economy, society and environment. Impact assessment helps the Ministry to demonstrate accountability, make investment decisions and learn more about policy effects for further improvement.

1.3 This report has been prepared largely from New Zealand government agency and OECD reports, and does not extrapolate beyond the data provided, or forecast future impacts.

1.4 The New Zealand science system has established strengths in government investment and researcher numbers. The business sector inputs and activity are rising relative to other sectors. University research publication outputs and commercialisation outputs have forged ahead.

1.5 Publications by New Zealand researchers appear to have an increasing international impact, the current level is close to the expected level, and there are areas of high impact.

1.6 Larger, longer-running, industry research programmes led by public research organisations have had a net positive impact on the New Zealand economy. Investment of public funds in these researcher-led programmes has been better for the economy than lowering the average tax rate would have been. Benefit-cost ratios ranged from two to seven to the economy per funding dollar invested.

1.7 Business-led research projects funded through Technology New Zealand have increased the productivity of participating firms by about five percent over their previous levels. The implied benefit-cost ratio to firms was between three and four per funding dollar invested.

1.8 The benefit-cost ratios do not include second order or spill-over effects, which, if included, would increase the ratio. Conversely, the benefit-cost ratio would reduce if co-funding by businesses were included as costs.

1.9 The overall upward trend in science system impact follows from increased inputs and outputs. Our ability to measure these impacts systematically reflects increased attention to research outcomes across the system.

2. Introduction

PURPOSE OF THIS REPORT

2.1 The purpose of this report is to identify the impacts of the New Zealand science system, and the inputs and outputs that led to these impacts.

2.2 As a policy advice agency, the Ministry of Research, Science and Technology (MoRST) has a particular interest in the impact of the science system on New Zealand's economy, society and environment. Impact assessment helps the ministry to demonstrate accountability, make investment decisions and learn more about policy effects for further improvement.

2.3 This report has been prepared largely from New Zealand government agency and OECD reports. It does not determine the relative benefits of a marginal increase in research personnel or investment inputs, or forecast future science or commercialisation impacts.

2.4 Impact evaluation, as defined by the State Services Commission of New Zealand,[1] *"links changes in outcomes to specific interventions, activities, services or outputs."*

2.5 Impact[2] is identified in this report at the point where an output of the New Zealand science system first shows influence in the science knowledge community or the market place.

2.6 Specifically, impacts were identified where research knowledge (e.g. a publication) was cited in a further publication, indicating that the earlier research had been useful to the science community;[3] or where there were measured budgetary effects on firms (e.g. changes in revenue) that firms attributed to research.

2.7 An outline of the organisation of the New Zealand science system is provided in Annex One.

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[1] Definition of impact evaluation see link: http://www.ssc.govt.nz/glossary/#I
[2] The use of term 'impact' varies across evaluation work internationally. The use of the term 'impact' in this report is consistent with the Public Finance Act. Outcomes are defined in the Public Finance Act as "*the impacts on, or consequences for, the community of the outputs or activities of Government.*"
[3] Metrics outputs and impacts of research are based on the assumption that knowledge is the result of research activity is, and that this knowledge is expressed through publication.

ROLE OF THE NEW ZEALAND SCIENCE SYSTEM

2.8 The New Zealand science system is a network of individuals and organisations, in both the public and private sectors, which interacts to produce and transfer scientific knowledge and technological know-how.

2.9 Networking and interaction are crucial to the health of the science system. New Zealand researchers are part of a mobile global community, and researchers from many nations contribute to New Zealand research impacts.

2.10 The science system includes research that is aimed at asking (and sometimes answering) fundamental questions about the universe (basic research), as well as research aimed at solving technological problems to benefit individuals, industry and communities (applied research).

2.11 Basic and applied research are types of research and (experimental) development (R&D). The OECD long-standing, formal definition of R&D is:

Research and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications.[4]

2.12 The Government is a key investor in science and therefore plays a leadership role in the science system. The Government invests in science to provide critical and competitive capability in research that meets the Government's long-term role of protecting national security, and maintaining the socio-economic well-being of New Zealanders and their natural environment. Government also supports industry investment in R&D, as increased industry R&D contributes to realising government goals.

2.13 Science system policy is designed to influence or drive the science system.

2.14 The New Zealand policy environment for science over the past 15 years has seen different arrangements of government funding to align with phases in thinking about the nature and purpose of the science system:

(a) 1995 to 1998 – science funded for public good benefit.

(b) 1999 to 2003 – output class size is balanced against priority.

(c) 2004 to 2008 – funding for outcomes rather than input-based.

(d) 2009 – measurable benefits, infrastructure and transfer sought.

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[4] OECD (2002) *Frascati Manual: Proposed standard practice for surveys on research and experimental development*. OECD, Paris.

MEASUREMENT OF THE IMPACTS OF NATIONAL SCIENCE SYSTEMS

2.21 Measurement of the impact of any science system is difficult.[5] This report provides our current understanding in terms of indicators and measures currently used by other OECD nations.[6]

2.22 This section outlines how 'input', 'output' and 'impact' are measured.

2.23 **Inputs** (funding and personnel) are largely measured by research contract data and national surveys of research organisations and businesses.

2.24 **Outputs** of research, such as knowledge generation, are measured through scientific research publications and patents. In the market place, outputs are measured as numbers of new products, processes and services, and spin-out companies; and in higher education, outputs of human capability are measured as the number of graduating and post-doctoral students. Numbers of collaborations between research institutions are also outputs.

2.25 **Impacts** as defined in this report are felt at the point where the outputs of research first affect the scientific community or market place.

(a) Citation rates are a measure of the impact of scientific research publications (e.g. papers). A citation in another publication shows that a publication was useful as it contributed to new knowledge.

(b) Typically, we may see economic impacts in the form of additional sales or reduction in costs to a firm. These impacts have an effect on the organisation's or nation's output. Research knowledge is said to 'spill-over' where a firm cannot appropriate all of the benefits of its investment in R&D to itself; measurement of spill-over is more difficult than measurement of benefits to firms.

(c) Non-economic impact (e.g. changes in the behaviour of firms, people, or wildlife) may also result from research. These impacts are often better described through case studies, than by aggregate statistics or total dollar values.

2.26 **International comparisons** add to our understanding of the impact of the New Zealand science system.[7]

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[5] Australian Government Productivity Commission (2007), *Public Support for Science and Innovation,* Australian Productivity Commission, Canberra.
[6] OECD (2010). *Measuring Innovation: A New Perspective*. OECD Publishing.
[7] The OECD produces sets of science and technology indicators that can be used for international comparisons.

3. Inputs to the New Zealand science system

INTRODUCTION

3.1 Inputs to a science system are primarily the dollar value of funds invested and the number of full-time equivalent research personnel employed.

3.2 Nations measure science inputs using research contract data and statistics from national surveys of research organisations and businesses.

3.3 New Zealand research programmes, over their lifetime, often blend government research, science and technology investment with tertiary education research funds and business R&D investment or co-investment; there can also be charity or lottery board funding, and funding from overseas. Thus, it is often difficult to attribute outputs of research to any particular input.

3.4 Gross expenditure on R&D (GERD) is the sum of business (BERD), higher education (HERD) and government (GOVERD) expenditure on R&D.

3.5 This chapter describes the inputs of research investment dollars and research personnel numbers to the New Zealand science system.

3.6 Further statistics on these inputs are available in MoRST, and joint MoRST-Statistics New Zealand publications through the following web links:

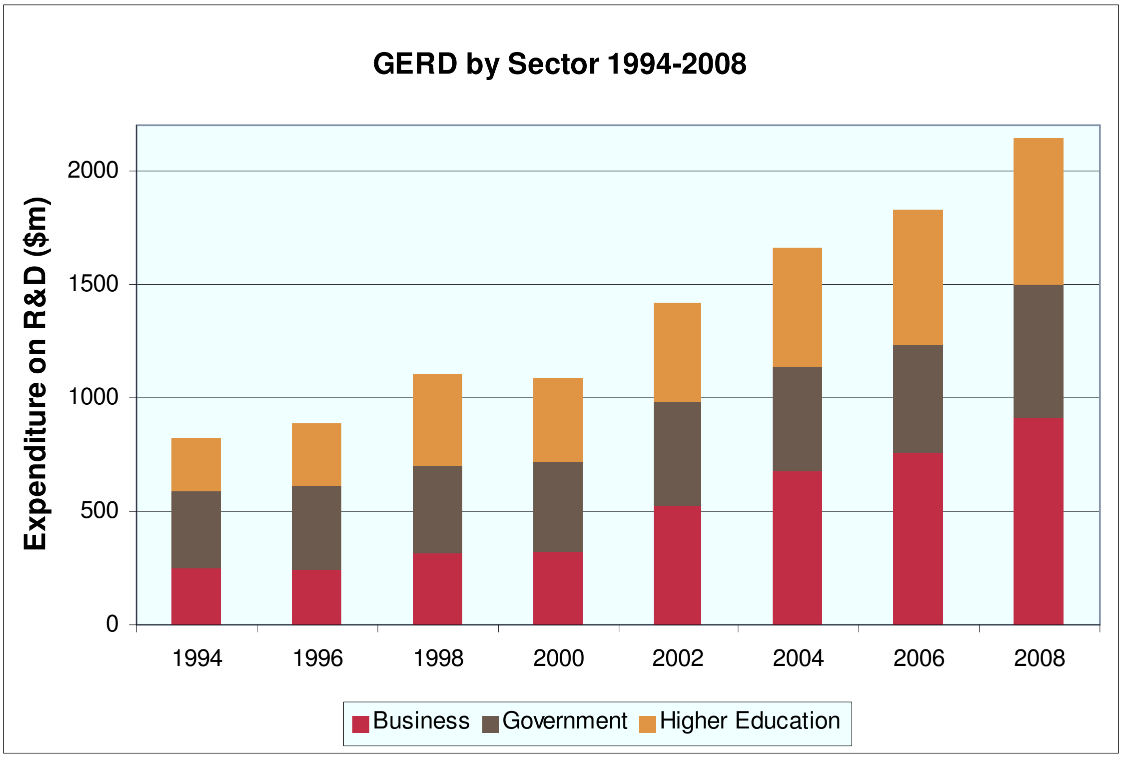
INPUT	DATA SOURCE
Investment dollars and personnel numbers	Research, Science & Technology (RS&T) Scorecard http://www.morst.govt.nz/publications/a-z/r/scorecard/
	Public Sector Financing of Research surveys http://www.morst.govt.nz/publications/statistics/financing-research/
	R&D in New Zealand - A Decade in Review http://www.morst.govt.nz/publications/a-z/r/decade-in-review/
	R&D surveys http://www.morst.govt.nz/publications/statistics/rd-survey/

RESEARCH INVESTMENT DOLLARS

3.7 The New Zealand science system statistics follow internationally defined guidelines for measuring expenditure on R&D. The methodology for sampling businesses changed between 2002 and 2004 and so time series data must be read in two parts: 1994-2002 and 2004-2008.

3.8 ***Gross expenditure on R&D (GERD).*** This measure is the sum of expenditure on R&D carried out in each of the business, government and higher education sectors. The measure includes salary and wages for research personnel which was 52 percent of GERD in 2008. New Zealand spends about 0.2 percent of the world's R&D budget.

3.9 The chart below shows the steady increase in expenditure on R&D over time, broken down by the business, government and higher education sectors.



3.10 The business sector carried out 43 percent ($913 million) of all expenditure on R&D (GERD) in New Zealand ($2,140 million) in 2008, a marginal increase from 42 percent in 2004. New Zealand business funded 40 percent ($859 million) of the 2008 year total R&D ($2,140 million), a marginal increase from 38.5 percent in 2004. Other funding sources were government (43 percent) universities (9 percent), overseas (5 percent) and other e.g. charitable donations (4 percent).

3.11 *International comparisons.* The standard OECD metric for comparing nations' R&D input to its economy is gross expenditure on R&D (GERD) as a percentage of GDP. This ratio is used to account for the size of each nation's economy.

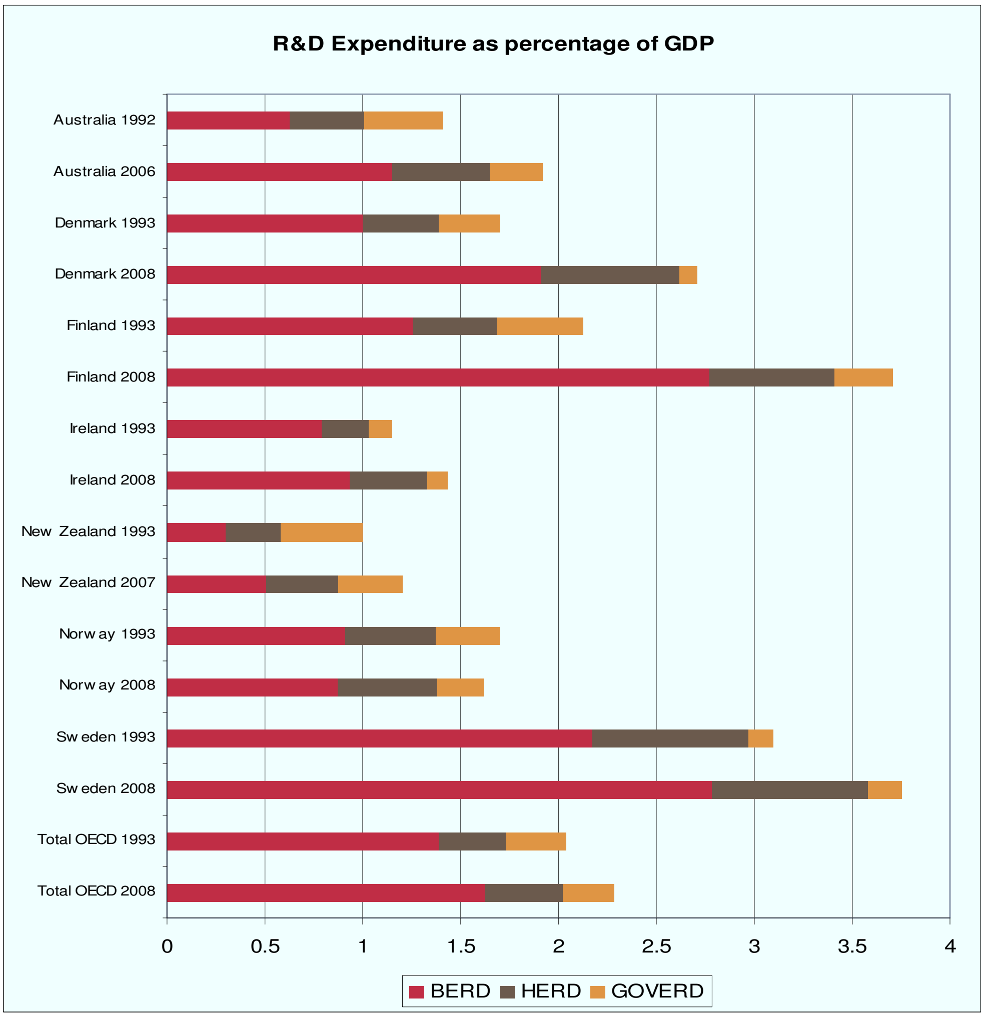
3.12 New Zealand lags behind the total OECD on this input measure.

3.13 When New Zealand figures for GERD as a percentage of GDP are compared against similar nations (Australia, Denmark, Finland, Ireland, Norway and Sweden), three significant aspects of the input funding are apparent:

(a) The ratios of GERD and business expenditure on R&D (BERD) as a percentage of GDP are lowest for New Zealand.

(b) New Zealand's increase in BERD as a percentage of GDP is higher than all but Finland.

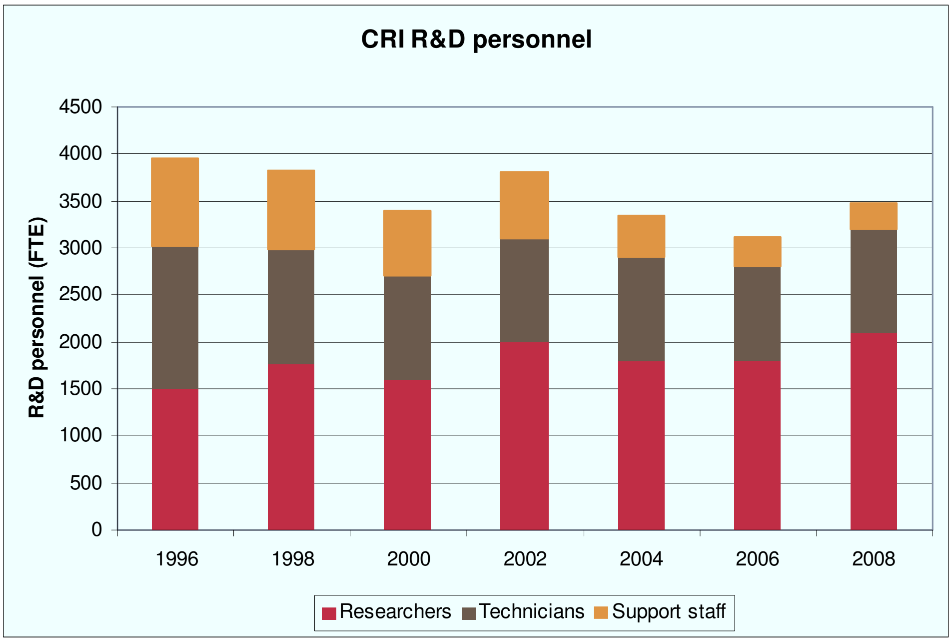
(c) Government expenditure on R&D in New Zealand (GOVERD) is among the highest as a percentage of GDP, but like most nations, has dropped over the 10 year period.



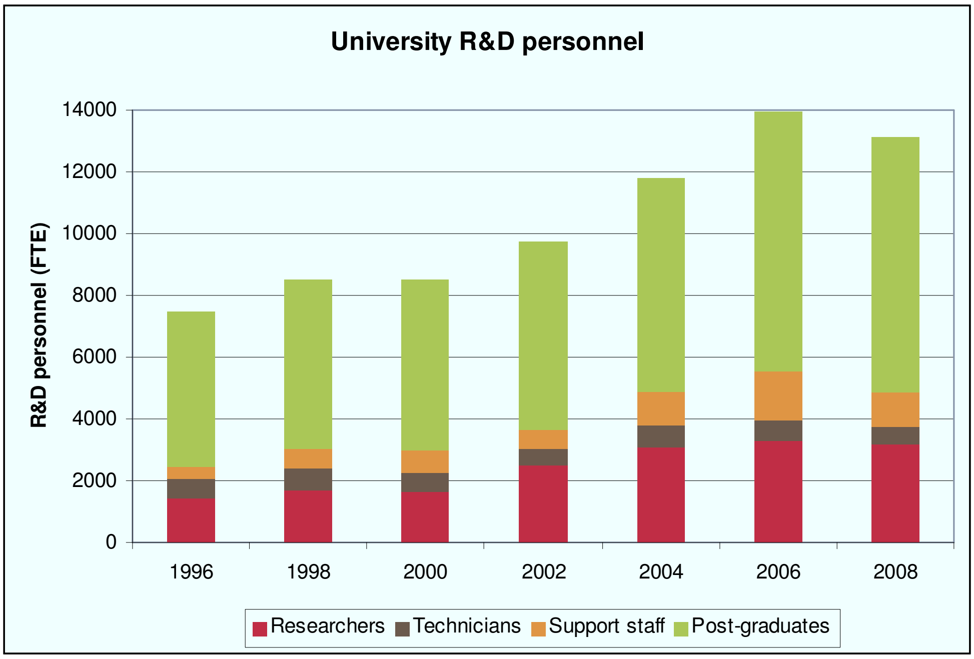
RESEARCH PERSONNEL NUMBERS

3.14 Human capability measurements of science distinguish between people based on their tertiary qualification. In general, a scientist is a doctor of philosophy (PhD) or a doctor of science (ScD), and a technician typically has a bachelor's or master's degree.

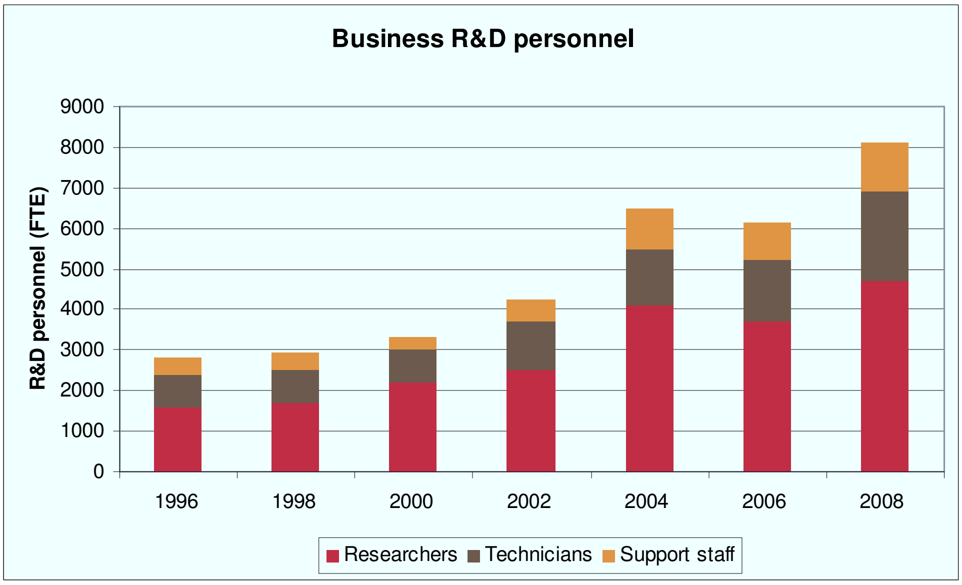
3.15 *CRI personnel.* Total CRI personnel numbers have declined since 1996; however, the number of researchers has increased.



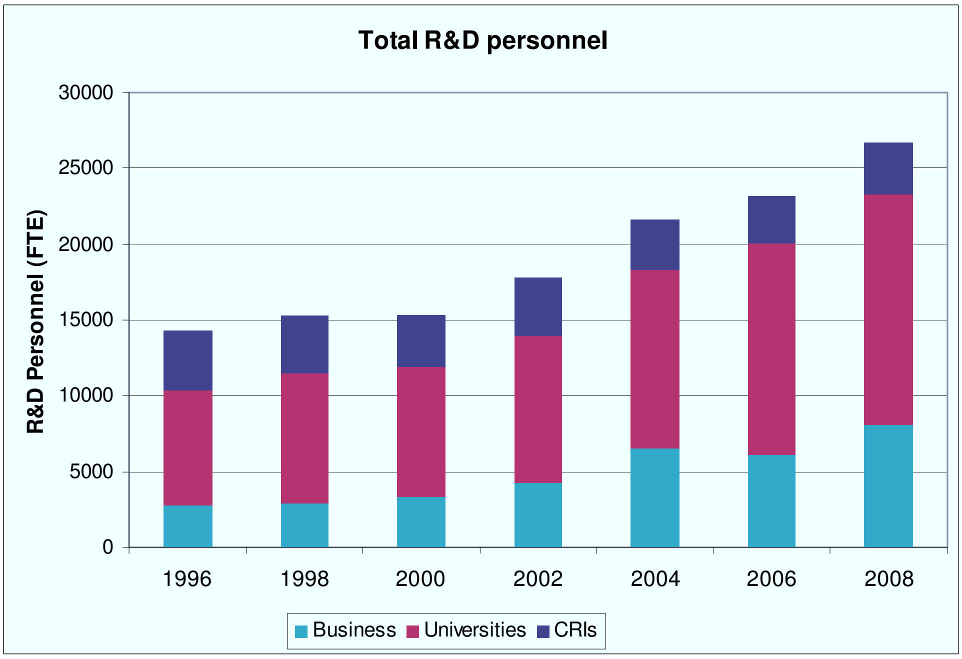
3.16 *University personnel.* University research personnel numbers have steadily increased since 1996.



3.17 ***Research personnel in the business sector.*** The number of researchers has increased in the business sector more rapidly than elsewhere. Note that between 2002 and 2004 there was a change in the method of surveying firms.



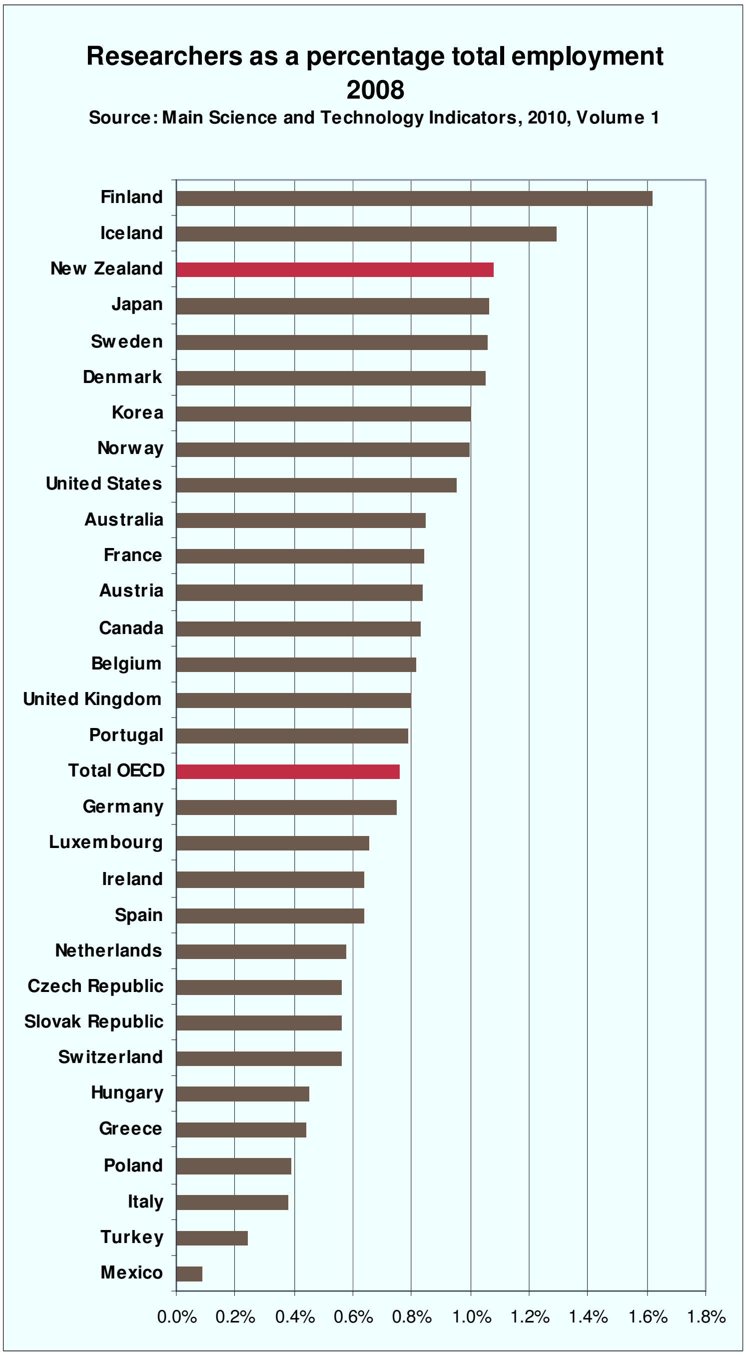
3.18 ***Total research capability.*** New Zealand research capability has increased consistently since 2000. The growth in numbers of R&D personnel in universities and in business has been considerable.



3.19 *International comparisons.* The standard OECD metric for comparing research personnel input is the number of full time equivalent researchers as a percentage of total employment. This ratio is used to account for the size of each nation's employed population.

3.20 New Zealand is well ahead of the total OECD on this measure of input to its science system.

3.21 New Zealand has more researchers as a percentage of total employment than Australia, Denmark, Ireland and Sweden. Across the OECD, New Zealand is third behind Finland and Iceland.



4. Outputs of the New Zealand science system

INTRODUCTION

4.1 Outputs from knowledge generation are measured through publications and patents; in the market, outputs are measured as numbers of new products, processes and services, and spin-out companies; and in human capability growth, through numbers of graduating and post-doctoral students. Collaborative national and international endeavours are also outputs of specific science policies.

4.2 This chapter describes the outputs of:

(a) publications of scientific papers

(b) protected intellectual property such as patents

(c) commercial outputs including new products, processes and systems, and spin-out companies

(d) tertiary graduate numbers in the science, health, engineering and information technology fields

(e) national and global collaboration and networks.

4.3 This report uses data from the following sources:

OUTPUT	DATA SOURCE
Publications	Bibliometric studies http://www.morst.govt.nz/publications/statistics/bibliometrics/
Intellectual property	Scorecard 2009 http://www.morst.govt.nz/publications/statistics/scorecard/
Commercial outputs	R&D surveys http://www.morst.govt.nz/publications/statistics/rd-survey/ Evaluation and economic impact studies http://www.morst.govt.nz/publications/evaluations/Review-of-Economic-Impact-of-Industry-Research/ http://www.morst.govt.nz/publications/a-z/t/technz-evaluation/ http://www.frst.govt.nz/files/TechNZ%20Evaluation.pdf
Tertiary graduates	Education counts section of the Ministry of Education website http://www.educationcounts.govt.nz/statistics/tertiary_education/retention_and_achievement
Collaboration	National Bibliometric Report 2002-2007 http://www.morst.govt.nz/publications/statistics/bibliometrics/ Research, Science & Technology (RS&T) Scorecard http://www.morst.govt.nz/publications/a-z/r/scorecard/

PUBLICATION OUTPUTS

4.4 Researchers often make the results of their scientific research (knowledge outputs) publicly available through publications. Publications may be individual papers published in their own right or as part of a periodical, or conference proceedings, or as a book, or chapter within a book.

4.5 Publications-per-year is a measure New Zealand's science output. The number of publications per year increased by 56 percent from 2002 to 2007.

4.6 University researchers, in particular, are expected to publish. Seventy-one percent of our publications had authors from higher education institutions, and between 2002 and 2007, higher education institution publication output increased by 78 percent.

4.7 Most New Zealand-authored publications were in the fields of medicine (33 percent of total New Zealand publications), agricultural and biological sciences (21 percent), biochemistry, genetics and molecular biology (15 percent) and environmental science (11 percent).

4.8 *International comparisons*. On average, New Zealand produces 0.7 percent of the world's scientific publications (it funds 0.2 percent of world research).

4.9 Agricultural and biological sciences, and environmental science, are far more prominent in New Zealand's research publication output than in the OECD as a whole. They make up 33 percent of New Zealand's publications, and 13 of total OECD publications.

4.10 Engineering publications from New Zealand were under-represented. The rate of publication in physics, astronomy and materials science was low.

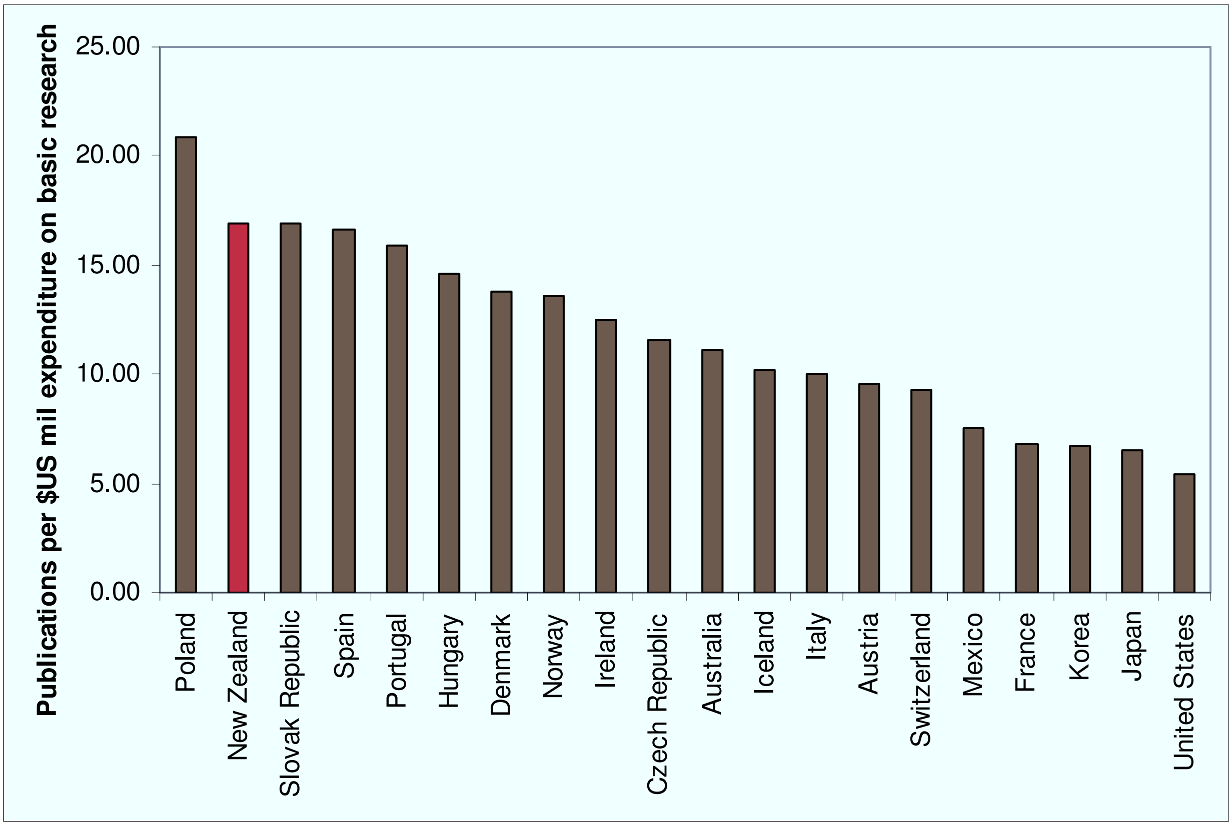
4.11 When comparing the cost of producing the publications, New Zealand ranks highly. New Zealand authors have more papers published per US$ million gross expenditure on R&D, and per US$ million of expenditure on basic research (which is a type of R&D) than do researchers from any other OECD nation except Poland.

4.12 New Zealand publishes more papers per US$ million expenditure on basic research that the comparator nations Australia, Ireland, Finland, Denmark and Sweden.

4.13 The United States, Japan and Korea have high relative costs for publications, both per US$ million gross expenditure on R&D and per US$ million basic research.

4.14 The chart below ranks countries by the number of publications per US$ million expenditure on basic research. New Zealand ranks very highly in this indicator of research efficiency.

Publications per US$ million basic research 2002-2007



PROTECTED INTELLECTUAL PROPERTY OUPUTS

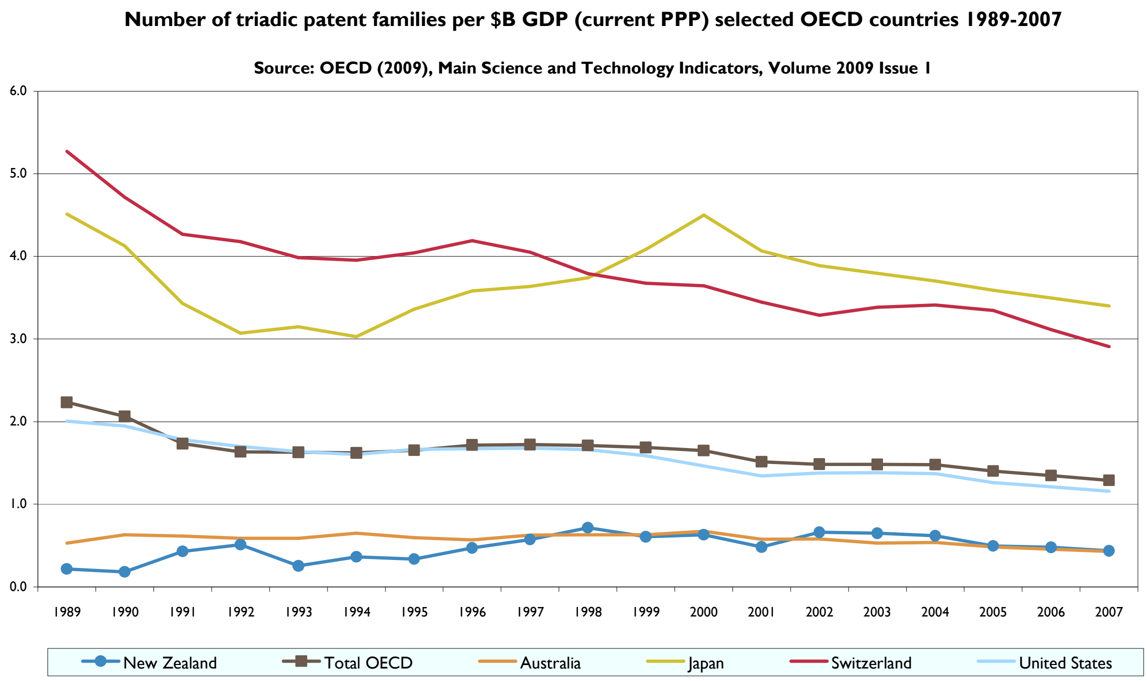
4.14 Outputs of commercially interesting research may be protected rather than published. The balance between open publication, use of trade secret, licensing or patent protection of research outputs varies considerably between research teams, and over time.

4.15 New Zealand patenting rose in the 10 years up to 1998, levelled off, and is now showing a slow decline.

4.16 *International comparisons*. In the past 10 years, New Zealand had a similar trend in patents (reported as the number of triadic patent families per billion dollars of GDP[8]) as did Australia.

4.17 The high patenting countries are Japan and Switzerland, with the United States patenting activity being very close to the OECD total.

4.18 The total OECD trend is a slow decrease in this measure of patenting activity over the past 20 years.



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[8] Note (1) A patent family is a set of patents filed in various countries to protect a single invention. Patent families are used with the intention of improving international comparability. The patent families reported here refer to triadic patent families: i.e. those that have been filed at the European Patent Office (EPO), the Japan Patent Office (JPO), and granted by the US Patent and Trademark Office (USPTO).

COMMERCIALISATION OUTPUTS

Spin-outs

4.19 A spin-out is a firm formed when an employee or group of employees leave an existing entity to form an independent start-up firm. A research organisation or university may support this action where the work of the spin-out company is not consistent with the primary role. Spin-outs are important sources of technology diffusion in high technology industries.

4.20 Numbers of spin-outs have become an international measure of commercialisation, when normalised using the number per US$1 billion R&D funding, even though there may be some variation in the capital raised and the survival rates of the spin-outs.

4.21 A study of spin-out companies from projects funded by the Foundation for Research, Science and Technology (the Foundation)[9] found that there has been a significant increase in both university and CRI spin-outs after the year 2000. The study reported that spin-out formation from New Zealand universities on a per-dollar basis was greater than in the United States, although fewer than in Australia and Canada.

4.22 For the past three years, the total number of spin-out commercial activities from research contracts managed by the Foundation was about 40, with the number of people employed being around 300.[10] Most spin-outs were in biotechnology, animal and plant production and primary products. Others were in manufacturing and engineering, information and communication services, health, environment and energy.

4.23 The NZVCC 2008 report[11] on university commercialisation stated that 29 new start-ups were formed by university commercialisation offices between 2003 and 2006, bringing the number up to 44. The number of full-time staff employed by these start-ups had grown from 198 to 363.

4.24 Not all spin-out companies endure. Some may be taken over or merged with other companies, relocate overseas, or simply not survive in the competitive environment. Difficulty in raising capital is a problem for spin-outs; this lack of capital may limit their lifespan and impact.

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[9] http://www.frst.govt.nz/library/evaluations/research-investment-strategies/spinouts
[10] MoRST Scorecard 09
[11] NZVCC (2008). University research commercialisation: Paying dividends for New Zealand. http://www.nzvcc.ac.nz/files/u2/NZVCC_Uni_ResearchFIN_1C59D.pdf

NATIONAL AND GLOBAL NETWORKS, AND COLLABORATION OUTPUTS

4.25 National and international collaborations involve researchers working across research institutions.

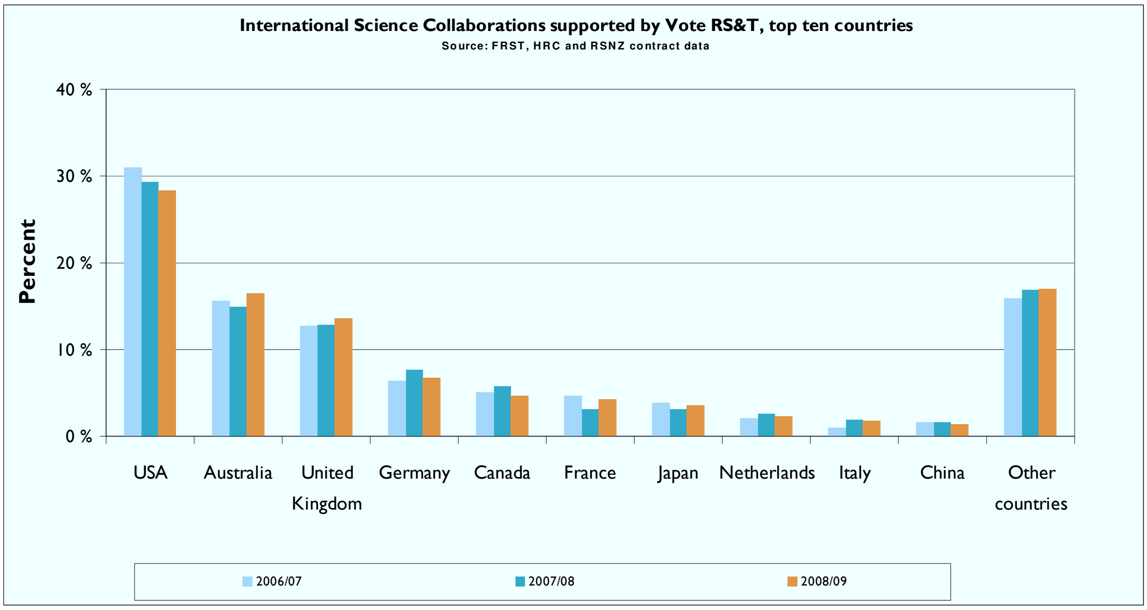
4.26 Bibliometric data shows that 84 percent of New Zealand's scientific publications during 2002-2007 involved multiple authors and 70 percent involved multiple institutions.

4.27 International collaborations are an important source of new knowledge and technologies that are drawn on and adapted for New Zealand's benefit. The extent of these linkages provides mutual benefit between nations, and allows the New Zealand science system to draw on science systems globally.

4.28 Government science and technology collaboration agreements exist between New Zealand and many countries. New Zealand researchers had co-authored publications with authors from 125 countries between 2002 and 2007 with 44 percent of the publications involved multiple countries.

4.29 Bibliographic data shows that by far the most common international co-authoring occurred with authors from the United States, Australia and the United Kingdom, and these collaborations have increased over time.

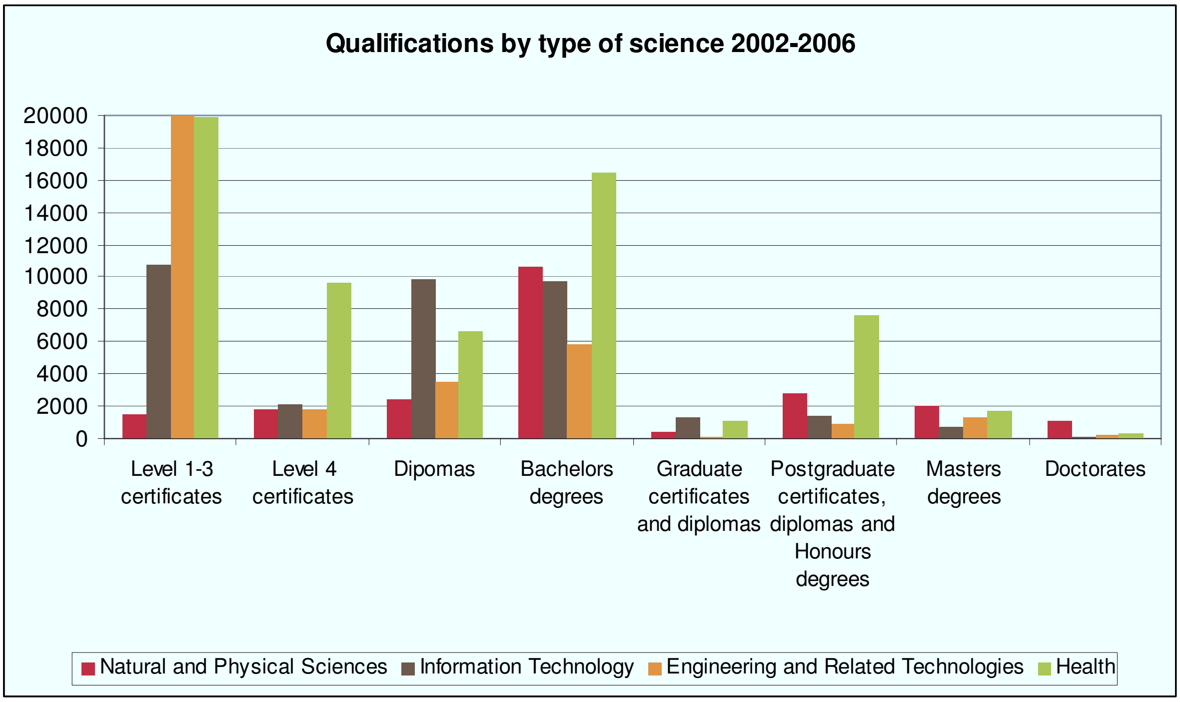
4.30 Contract data on research collaborations supported by the Government's investment (Vote RS&T) show similar results.



TERTIARY GRADUATE OUTPUTS

4.31 In New Zealand, the number of graduates in the wider science field at all levels increased between 2002 and 2006. Graduates from the natural and physical sciences, information technology, engineering and related technologies, and health are included in this analysis.

4.32 The distribution of graduates is consistent with the strengths in the New Zealand science system.



4.33 New Zealand currently produces a large group of technician qualifications in engineering, information technology and health at qualification levels one to three. The qualifications at these levels are largely trade certificates.

4.34 Overall science enrolment and bachelor graduate numbers rose, with the exception of those studying information technologies. The number of postgraduate certificates and diplomas increased for all science areas, and is high in the health sector, with nearly all being in nursing.

4.35 About half of the natural and physical science graduates at masters level studied biological sciences. The large numbers in the health area are mostly in nursing and public health.

4.36 Engineering graduates as a percentage of new degrees was lower than in Australia, Denmark, Finland, Norway and Sweden.

5. Impacts of the New Zealand science system

INTRODUCTION

5.1 **Impact** is identified in this report at the point where an output of the New Zealand science system first shows influence in the science knowledge community or the market place.

5.2 This chapter outlines impacts in the following forms:

(a) Knowledge impact – citation of publications including scientific papers. Citation rates are used to measure of the impact of scientific research publications (e.g. papers) that are the outputs of knowledge systems (e.g. universities).

(b) Economic impact – these are measures of the primary or higher order benefits of selling or introducing a product, process or system that was an output of a R&D project. Measures include market value of commercial outputs, reductions in production costs and the turnover and export earnings of spin-out companies.

5.3 This report uses data from the following sources:

IMPACT	DATA SOURCE
Knowledge	National Bibliometric Report 2002-2007 http://www.morst.govt.nz/publications/statistics/bibliometrics/
Economic	See table in Economics section of this chapter

KNOWLEDGE IMPACT – CITATION RATES

New Zealand research publications appear to have increasing international impact.

5.4 Knowledge has an impact when it is high quality or highly cited, and when it increases the capability of the researchers carrying out the work.

5.5 Bibliometric data on the citation rates for research publications (outputs) provide a good measure of the impact of the research in generating knowledge that is useful to the science community.

5.6 The New Zealand citation impact relative to the rest of the OECD is slightly under, but very close to, the expected rate.

5.7 The impact of New Zealand publications in some subject areas is rather higher than would be expected on the basis of subject-normalised world rates. These areas are:

- veterinary
- nursing
- health professions
- physics and astronomy.

5.8 The high impact for physics and astronomy subject areas is of interest, as New Zealand's contribution to the world output in these areas is relatively low.

5.9 A more finely-grained analysis shows that, in addition to the veterinary, nursing and health professions, and physics and astronomy; there is a higher than average impact in building and construction; chemical engineering; law, business, management and accounting and mathematics.

ECONOMIC IMPACT – OVERVIEW

5.10 Economic impact studies attempt to measure the primary and higher order benefits of selling or introducing a product, process or system that was an output of an R&D project.

5.11 Economic impact can be seen in terms of a combination of the following:

(a) benefit to the firm or research provider

(b) benefit to the industry sector

(c) benefit to New Zealand — through benefits to society that are economically meaningful — like peace and security, and better health.

5.12 Within each of the above levels of impact, there are:

(a) tangible and quantifiable benefits — such as a new good or service; or a quality improvement (e.g. better pastures)

(b) intangible benefits to end-users — such as tacit knowledge, skills and consumer confidence. These types of benefits also build the absorptive capacity of the end user to exploit other knowledge, such as international knowledge

(c) unintended benefits to the funder of the research

(d) intangible benefits to researchers — that builds their absorptive capacity for knowledge and technology, including international knowledge and technology; this enables them to exploit, commercialise and develop new technologies

(e) unintended benefits to others — both locally and internationally.

5.13 Benefits can accrue in:

(a) short-term — during the period of the research project

(b) medium-term — during the period following the research project

(c) long-term — many years and possibly generations after the research.

5.14 Reports on economic impact of R&D include:

REPORTS

- Australian Government Department of Innovation, Industry, Science and Research (2010), *Australian Innovation System Report 2010*, Department of Innovation, Industry, Science and Research, Canberra.
- Australian Government Productivity Commission (2007), *Public Support for Science and Innovation,* Australian Productivity Commission, Canberra.
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- Insight Economics Pty Ltd, (2006), *Economic Impact Study of the CRC Programme, Prepared for the Australian Government Department of Education, Science and Training*, Insight Economics, Melbourne.
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ECONOMIC IMPACT – RESEARCH FOR INDUSTRY

Larger, longer-running RFI research programmes have paid for themselves.

5.15 Research for industry (RFI) was a long-running government fund that was focussed on strategic research to increase the global competitiveness of New Zealand firms. The fund was in place from 2000 to 2009. Industry contributed co-funding to RFI-funded projects through firm-level and industry levy contributions (contributions are also made by government departments and community service organisations). Research consortia were introduced in 2002 as a purchasing instrument within the RFI fund, with greater industry engagement and 50:50 co-funding.

5.16 In 2009, the Foundation funded the review of aspects of the Research for Industry Fund. Infometrics investigated firm-level impacts, particularly from the 2002 funding year.

5.17 Infometrics reported that:

(a) the fund was increasing the global competitiveness of end-users

(b) the research appeared to be highly successful from a science quality perspective

(c) industry believed that RFI was working well

(d) there was a reasonably good success rate in terms of commercialisation of technologies, but also a significant number of contracts where there has been no commercialisation of technologies

(e) gross firms margins rose by an average of five to ten percent, driven by higher capital productivity or higher selling prices and sales volume

(f) there was good user uptake when there was a market opportunity and researchers and users had a mutual interest in the outcome and worked together to that end.

5.18 Infometrics reported that although companies were often confident of the benefits received, companies found it difficult to quantify those benefits in most cases, even where quantification was theoretically possible.

5.19 The Foundation's 2009 investment impact report contained further information from the Infometrics review of RFI, shown in the table below:

MEASUREMENT	AVERAGE IMPROVEMENT
Capital productivity	About 7%
Gross margins	Over 5%
Selling prices	5%
Sales volumes	About 4%
Labour productivity	About 2%
Reduction in production costs	About 1%

5.20 The benefits included raising production efficiency (13 cases), producing new higher-value products (six cases) and improving the quality of existing products (eight cases). Implementation costs were the biggest hurdle.

5.21 The results were "additional" in that the benefits would not have occurred without the research. Without RFI funding, in some cases, the project would not have proceeded, and in others, the pace of the technological innovation would have slowed. Spill-over benefits included the increased capability of researchers, manufacturers, sellers and distributors.

5.22 In 2010, MoRST funded Infometrics to assess[12] the economic effects of five larger, longer-running RFI research programmes or sets of projects.[13] Infometrics assessed an annualised RFI investment of $25 million, which is roughly 10 percent of the average 2002-2008 RFI annual investment of $276 million.

5.23 In very simple terms, the assessment looked at the effects of the research on private consumption, exports, imports, GDP and a related measure—real gross national disposable income (RGNDI), along with changes in terms of trade, real exchange rate and mean household tax rate.

5.24 The study found that modelled GDP and RGNDI increased in the five scenarios, implying that RFI-assisted research had led to net improvement in productive efficiency and/or allocative efficiency.

5.25 The study included a counterfactual analysis that considered what the net effect would have been if the money that went into RFI was instead used to lower the average tax rate.

[12] The assessment used was general equilibrium modelling (GEM).
[13] Their work is presented as a chapter in Ministry of Research, Science and Technology (2010), *Economic Impact of Industry Research: A Review of the Food & Fibre, Manufacturing & Services, and Research Consortia Outputs of the Research for Industry Fund,* MoRST, Wellington.

5.26 The modelling showed that the larger, longer-running RFI research programmes had paid for themselves. For each scenario, lowering the average tax rate would have been less effective than spending the money on RFI research. In other words, the increase in tax revenue arrising from economic growth (higher RGNDI) attributed to the RFI research was sufficient to have financed the RFI funding for that research.

5.27 The report discussed the relative effects of investing in research that improved productivity for commodity-based production compared to investing in high value products, with a preference made for research in high value products.

5.28 The sheep genomics programme was delivering the best return per dollar of RFI investment in spite of foreign consumers also being significant beneficiaries through lower commodity prices.

5.29 Infometrics modelled a sixth scenario as a special case. This research programme was large enough for modelling, some benefits had accrued, and its projected benefits indicated very significant benefit-cost ratios. Modelling showed that costs currently outweigh benefits, but that the breakeven point was well within the projected revenue benefits.

5.30 Further scenarios were considered, but the inputs to and benefits from these research programmes or sets of projects were too small for analysis by the modelling tool.

5.31 The summary of changes in aggregate economic welfare per unit RFI subsidy and per unit total investment for the scenarios is shown below:

SCENARIO	DESCRIPTION	ΔRGNDI/ RFI FUNDING	ΔRGNDI/ (RFI+CO-FUNDING)
RFI-1	Manufacturing	2.05	1.72
RFI-2	Forage grasses	2.12	1.63
RFI-3	Sheep genomics	7.07	2.07
RFI-4	Gold kiwifruit	2.33	1.96
RFI-5	Forestry	2.51	1.98

5.32 Two examples (manufacturing and forestry) illustrate the analysis:

5.33 ***Light Alloy Manufacturing and Communication Technologies.*** In an 'average year', government funding input was $4.2 million, in addition to other funding that was received. The RFI investment and co-funding was spent on R&D services.

5.34 As a result, there were new export and domestic sales. The latter were primarily of equipment that raises the productivity of pastoral farming.

5.35 The model was designed so that there would be no change in total employment or total capital stock. Changes in outputs had to come from productivity improvements or at the expense of output from other industries.

5.36 The model calculated that about 20 percent of the valued-added for the manufacturing example would be at the expense of other industries.

5.37 The overall change in exports was $7.3 million which was below the value of exports attributable to the R&D. This was because fewer exports from other industries were required. As a result, more resources would flow into private consumption, which would rise by $11.6 million, and RGNDI would rise by $8.6 million.

5.38 In simple terms, for every dollar of public funding, the return (in terms of RGNDI) is about $2.05. There would be no change in the mean tax rate paid by households, as the annual $4.2 million government subsidy can be financed by the increase in tax revenue stemming from economic growth (higher RGNDI), without the need to actually adjust personal taxes.

5.39 ***Forestry Innovations***. RFI funding of $37 million was spread over about nine years, giving an 'average year' government funding input of about $4.1 million. The RFI investment and co-funding was spent on R&D services which led to software products for forest pruning and harvesting schedules, and timber treatment and assessment to raise wood quality.

5.40 As a result, software sales to the forestry and logging industry led to higher total factor productivity in the forestry industry, with reallocation of resources from other industries.

5.41 For every dollar of public funding, the return (in terms of RGNDI) is about $2.31. No measurable increase on household tax rates (that is not more than 0.1 percent) would be required to finance the RFI investment.

ECONOMIC IMPACT – TECHNOLOGY NEW ZEALAND

Participation in TechNZ is associated with improved firm productivity measures

5.42 Technology New Zealand (TechNZ) is a business investment programme that is designed to support companies and people undertaking research and development projects that result in new products, processes or services.

5.43 Infometrics reviewed the TechNZ programme in 2001 and found that firms undertaking TechNZ research had experienced higher growth than they had previously, that revenue increased and R&D programmes were strengthened or maintained. Firms also reported that their appreciation of R&D and relationships with research organisations improved.

5.44 In 2009, Infometrics reviewed TechNZ again. The results are summarised below:

MEASURE	2009 RESULT (INCREASE)
Volume of sales	16% ($302 million)
Volume of exports	19%
Productivity	5%
R&D capacity	in 25% of projects

5.45 Infometrics calculated that, assuming a 50 percent value add from the volume of sales figures, there was implied an annual contribution of $150 million to GDP over recent years. The result is an indicator of economic impact, but it is not a complete assessment of the net effect of TechNZ on GDP.

5.46 With a total investment of $36.9 million in projects that yielded these benefits, there is an implied 4.2 dollars benefit for each dollar invested. Infometrics noted that this result was highly skewed by the presence of a company with large sales volumes in the sample and that when that one company is excluded; the benefit-cost ratio falls to 2.9.

5.47 These figures identify the private benefits of investing in R&D. The public or social benefits of R&D identified internationally indicate that the benefit to New Zealand's GDP from TechNZ is likely to be several times more than $150 million.

ECONOMIC IMPACT – HEALTH RESEARCH

Work in progress on measuring impacts

5.48 The February 2010 Baseline Investment Impact Report of the Health Research Council (HRC) reported that it is working on a new investment model that will fund research that is positioned within practice or service delivery to meet short- to medium-term challenges in health. Part of that work is the development of an evaluative framework to monitor the outputs, impacts and outcomes of research funded by the HRC.

5.49 Internationally, New Zealand health research has a high scientific knowledge impact as shown by bibliometric studies. For research to have a benefit to population health, the research must change health practice.

5.50 The HRC has reviewed engagement of researchers with people responsible for making changes to health practices, and people who use health services. The HRC found that two thirds of researchers engage appropriately with these groups of people. In the third that did not engage, the impact of the research is reduced, as results are less likely to be incorporated into health policy or practice. With the introduction of the evaluation framework, the HRC expects that engagement will increase.

ECONOMIC IMPACT – COMMERCIALISATION

University research

Universities are matching or significantly outperforming overseas benchmarks

5.51 University commercialisation activities are wide ranging. Each university commercialisation office has taken a different approach to extracting economic value from its research.

5.52 The NZVCC 2008 report on university commercialisation revealed a total income in the four years 2003–2006 of $1.2 billion dollars, with income rising to $350 million a year.

5.53 Revenue from contract research carried out at universities increased from $201 million in 2003 to $275 million in 2006, amounting to nearly a billion dollars over four years.

5.54 Consultancy activities over the same period have brought in a further $65 million of revenue, and over $155 million of capital has been raised for start-up companies.

5.55 Revenues from technology licensing have increased from just under $4 million in 2003, with 97 active licenses, to over $10 million in 2006, with 210 active licences.

Spin-outs

The commercial value of spin-out activities has dramatically increased

5.56 The total annual sales revenue from spin-outs resulting from Foundation-funded research was about $29 million in 2006/07 and 2007/08. Revenue fell to $23.7 million for 2008/09, with $10.2 million export earnings.[14]

5.57 The combined market capitalisation of university spin-outs grew from $76 million in 2003 to $1,100 million in 2006.

[14] MoRST Scorecard 09

6. Summary

6.1 The inputs, outputs and impacts, focussing on economic impact of the New Zealand science system are summarised below.

INPUTS

6.2 The New Zealand science system inputs of investment and personnel are characterised by steady growth in government investment with low, but rising business sector investment, and steady growth in total research personnel numbers, with an increasing proportion of researchers.

6.3 International comparisons show that New Zealand's expenditure on research, as a percentage of GDP is low, but New Zealand is third in the OECD for number of researchers as a percentage of total employment.

OUTPUTS

6.4 New Zealand science system outputs, in the form of publications, patents, spin-out companies, networks and tertiary graduates, contribute to the distinctive New Zealand science system profile.

6.5 One third of New Zealand-authored publications are in medicine. These together with agricultural and biological science papers make up half of the publications. Growth in publication was strongest in the university sector. New Zealand ranks second behind Poland for the number of publications per million US dollars expenditure on basic research.

6.6 New Zealand's patent per research dollar trend is following the OECD's downward pattern; New Zealand and Australia have similar patent rates.

6.7 Spin-out company numbers are increasing, and formation on a per-dollar basis is greater than the United States, but lower than Australia.

6.8 The 70 percent of New Zealand scientific papers that involve multiple institutions shows that researchers are developing and using science networks. Our international collaborations are predominantly with the United States, Australia and the United Kingdom.

6.9 Tertiary graduate output is consistent with the strengths of the New Zealand science system, with particular strength in health science.

IMPACTS

6.10 New Zealand research publications appear to have increasing international impact measured by citations, and the current relative impact is close to the expected rate. Areas of high relative knowledge impact are veterinary, nursing, health, and physics and astronomy research.

6.11 Larger, longer-running, industry research programmes led by public research organisations have had a positive impact on the New Zealand economy. Investment of public funds in these researcher-led programmes has been better for the economy than lowering the average tax rate would have been. Benefit-cost ratios ranged from two to seven, per funding dollar invested, for programmes with suitable data for this analysis.

6.12 Business-led research projects funded though TechNZ has increased the productivity of participating firms by about five percent over their previous levels. The implied benefit-cost ratio of TechNZ to firms was between three and four per funding dollar invested.

6.13 The benefit-cost ratios for researcher-led and business-led projects do not include second order or spill-over effects, which, if included, would increase the ratio. Conversely, the benefit-cost ratio would reduce if the co-funding for research or commercialisation funds provided by firms were included as costs.

6.14 The impact of commercialisation of research has dramatically increased. University commercialisation revenue was $350 million in 2006 and revenue from Foundation-managed research reached $127 million in 2008/09.

CONCLUSION

6.15 The overall upward trend in science system impact follows from increased inputs and outputs. Our ability to measure these impacts systematically reflects increased attention to research outcomes across the science system.

Annex One Organisation of the New Zealand science system

INTRODUCTION

1.1 This annex describes the organisation of the New Zealand science system including the following types of research institutes:

- Crown research institutes
- universities including Centres of Research Excellence
- private sector and research organisations.

1.2 The organisation of our science system is a product the structure of the New Zealand economy. The primary sector dominates the economy, and much of our manufacturing involves food or bio technology. There is strong reliance on public research funds. Privately-funded research, while growing strongly, is low by international standards.

1.3 For twenty years until 2010, there was clear separation of the policy, purchase and provider roles in our science system. In 2010, the Government decided to amalgamate the policy ministry, MoRST, with its major funding and investment agency, the Foundation for Research, Science and Technology (the Foundation).

1.4 In New Zealand, there were approximately 24,700 full-time equivalent research personnel (FTEs) in 2008. Researchers made up 74 percent of all FTEs, and technicians held 16 percent of all research positions. Over half of the research population was employed by the university sector.

1.5 There is a growing connection between the science, education and business systems. Science, information technology, engineering and health students may receive part of their training or work experience alongside research teams at any of the research institutes, and internationally. This research may be partly funded by government and co-funded by business or industry associations.

1.6 Other organisations that may do research are polytechnics, wānanga (a tertiary institution that provides education in a Māori cultural context), hospitals and local authorities, and some of these partner with larger research organisations.

1.7 Large-scale research infrastructure is partly government-funded and shared across research institutions. Expensive infrastructure items and nationally significant databases are of growing significance.

CROWN RESEARCH INSTITUTES

1.8 CRIs were established in 1992 as Crown-owned, limited liability companies.

1.9 Their primary purpose is to undertake research for the benefit of New Zealand. In fulfilling this purpose CRIs are required by law to:

- undertake research for the benefit of New Zealand
- pursue excellence in all their activities
- comply with applicable ethical standards
- promote and facilitate the application of results of research and technological developments
- operate in a financially responsible manner and maintain their financial viability.

1.10 CRIs are government-owned to ensure that New Zealand maintains a critical mass and capability in strategic areas of science that are of long-term importance to this country.

1.11 Revenue for CRIs comes from both the public and private sector, with roughly half coming from funds administered by the government through the Foundation.

1.12 The CRIs deliver outcomes targeted at the Government's economic, environmental and social goals, including maintaining scientific infrastructure and science capability.

1.13 Each CRI was established around a productive sector of the economy, a grouping of natural resources or a particular public-good task, enabling each CRI to have a clearly-defined purpose and customer base.

1.14 In October 2009, the Government established the Crown Research Institute Taskforce to examine how CRIs could best deliver on national priorities, and respond to the needs of research users, particularly industry and business.

1.15 The Taskforce signalled a change in the direction and organisation of CRIs.

1.16 MoRST is leading the implementation of the recommendations of the Taskforce, and the recommendations are expected to have been largely implemented by July 2011.

1.17 The eight CRIs comprise:

- **AgResearch Ltd**, New Zealand's largest CRI, which undertakes research to create sustainable wealth in the pastoral and biotechnology sectors through science and technology. AgResearch is at the heart of the pastoral industries, food processing, textiles and innovative products.
- The **New Zealand Institute for Plant and Food Research Ltd (Plant and Food Research),** which was formed in December 2008 when HortResearch and Crop & Food Research merged. Plant and Food Research focuses on adding value to fruit, vegetable, crop and food products, and has research and commercial partnerships that include molecular biology, nutrigenomics, and fruit and seafood products.
- **Industrial Research Ltd (IRL),** which undertakes science, development and technology commercialisation in the areas of communication, information and electronic technologies, advanced materials and performance, intelligent devices and systems, pharmaceutical, biochemical and energy technologies, and complex measurement and analysis.
- **Institute of Environmental Science and Research Ltd (ESR),** whose work underpins the health and justice systems of New Zealand. ESR focuses on forensics, communicable diseases, food safety, pharmaceuticals, population and environmental health, toxicology, systems thinking and social science, and water management.
- **Institute of Geological and Nuclear Sciences Ltd (GNS Science),** which seeks to understand earth systems and technologies, and to transform this knowledge into benefits for New Zealand. GNS Science studies earth systems, and isotope and nuclear science and technologies. GNS Science is the centre of expertise for off-shore and on-shore mineral resources, geological hazards and their associated risks, and economic, social and environmental impacts.
- **Landcare Research New Zealand Ltd (Landcare Research Manaaki Whenua),** which focuses on New Zealand's biodiversity, reducing pest and disease impacts on ecosystems, the impacts of climate change, long-term health and viability of rural and urban environments, supporting businesses adopting environmentally sustainable and competitive practices.
- **National Institute of Water and Atmospheric Research Ltd (NIWA),** which provides a scientific basis for the sustainable management and development of New Zealand's atmospheric, marine and freshwater systems and associated resources.
- **New Zealand Forest Research Institute Limited (Scion),** which is dedicated to research that supports the New Zealand forestry industry and to build a stronger bio-based economy. Major research areas include sustainable design, new forests and forest science, and bio products development.

UNIVERSITIES, INCLUDING CENTRES OF RESEARCH EXCELLENCE

1.18 New Zealand universities undertake a sizable proportion of New Zealand's research activity.

1.19 University research funding comes largely from Vote Education through the Performance Based Research Fund (PBRF) ($242 million for 2009/10) and Vote RS&T, through contestable and stable funding, as well as from their own funds and research contracts. The purpose of the PBRF is to raise the quality and focus of research, and to provide incentives for improved investment in basic research in the tertiary sector.

1.20 The universities themselves determine the allocation of funds and, as a result, the institutions and the scientists they employ play an important role in determining what research is undertaken in New Zealand.

1.21 The eight New Zealand universities are:

- Auckland University of Technology
- Lincoln University
- Massey University
- University of Auckland
- University of Canterbury
- University of Otago
- University of Waikato
- Victoria University of Wellington.

1.22 Centres of Research Excellence (CoREs) were introduced in 2002/03. They are funded through Vote Education, and their purpose is to encourage the development of world-class research facilities in New Zealand ($35 million funding for 2009/10).

1.23 Each CoRE is hosted by a university, and comprises a number of partner organisations, including other universities, CRIs and wānanga.

1.24 The eight CoREs are:

- **Allan Wilson Centre for Molecular Ecology and Evolution** – molecular ecology and evolution (hosted by Massey University)
- **Maurice Wilkins Centre for Molecular Biodiscovery** – integrated research from genes to whole cell function and new treatments for cancer, diabetes and infectious disease (hosted by University of Auckland)
- **The MacDiarmid Institute for Advanced Materials and Nanotechnology** – advanced materials and nanotechnology (hosted by Victoria University of Wellington)
- **The Bio-Protection Research Centre** – advanced bio-protection technologies (hosted by Lincoln University)
- **National Centre for Growth and Development** – human and animal growth and development (hosted by University of Auckland)
- **Ngā Pae o te Māramatanga** – Māori development and advancement (hosted by University of Auckland)
- **The Riddet Institute** – functional foods and food ingredients with novel characteristics (hosted by Massey University)
- **The New Zealand Institute of Mathematics and its Applications (NZIMA)** – Mathematics and its applications (hosted by University of Auckland).

INFRASTRUCTURE

1.25 Governments invest in infrastructure where the tools are too expensive for a research organisation to own individually, but are necessary for researchers to meet time or quality parameters. CRIs along with universities are responsible for some of the most sophisticated science infrastructure in New Zealand.

1.26 Infrastructure includes the ultra-high speed optical fibre internet (KAREN), access to the Australian Synchrotron, CRI capability and backbone funding (of nationally significant databases), national measurements standards and genomics facilities.

PRIVATE SECTOR AND RESEARCH ORGANISATIONS

1.27 Like elsewhere in the world, privately-funded R&D is dominated by a small number of larger companies, which contribute to over half of business expenditure on R&D. New Zealand R&D-intensive firms are a mix of older, well-established companies and relatively young, smaller high-tech firms.

1.28 New Zealand has industry-linked research providers and private sector organisations that rely on funding from corporate, charitable and contestable government sources. The independent research organisations have areas of expertise, such as medicine.