National Bibliometric Report 2002–2007

National and International Benchmarking of New Zealand Peer-Reviewed Research Publication

JUNE 2010

The views expressed in this publication are those of the authors
and are not necessarily supported by the
Ministry of Research, Science and Technology.

ISBN: 978-0-478-06168-0 (ELECTRONIC)
FILE REFERENCE: SE240104
DATE: JUNE 2010

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PUBLISHED BY THE
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1. Executive Summary

1.1 This report presents a bibliometric analysis of New Zealand's peer-reviewed research publication 2002-2007. It identifies areas of focus and strength within New Zealand's research community, shows patterns of linkage and collaboration, and compares New Zealand's science performance with the rest of the OECD.

1.2 The analysis presented in this report is based on a Scopus customised dataset of OECD publications 2002-2007. Some analysis reported excludes 2007 (only reports 2002-2006) due to data or citation availability.

1.3 Major findings are that:

- The rate and impact of New Zealand publications has increased during the period 2002-2007. This is especially so in the Tertiary Education sector, which appears to be associated with changes to Tertiary Sector research funding.
- While the impact of New Zealand publications is generally average for an OECD nation, there are certain disciplines (especially in the medical sciences) where New Zealand research has a higher than average impact. This is the same as in previous bibliometric findings.
- New Zealand is a cost effective place to do research. It has a comparatively high rate of publication per dollar of R&D expenditure.

1.4 **Publication output**. For the period 2002-2007, Scopus recorded a total of 40,376 publications with at least one author affiliated to a New Zealand institution: an average of 6,729 per year.

1.5 **Publication rate**. In the period 2002-2007, New Zealand's annual publication rate increased by 56%. In comparison, the previous bibliometric report showed no significant change in New Zealand's publication rate between 1996 and 2001. While all sectors increased their publication rate between 2002 and 2007, the Tertiary Education sector has showed the largest increase.

1.6 **Scientific productivity**. Between 2002 and 2007, New Zealand ranked 11th in the OECD in research publications per capita, just behind the United Kingdom, Australia and Canada. New Zealand ranked 2nd in publications per dollar spent on basic research, 4th in publications per dollar of gross expenditure on research and development (GERD), and 14th in publications per researcher. New Zealand's international rankings have not changed significantly since the previous bibliometric report in 2005.

1.7 **Areas of focus**. Publications with at least one New Zealand author made up 0.7% of total OECD publications between 2002 and 2007. The subjects where

New Zealand was most prolific (contributing greater than 1.4% of total OECD publications) were:

- Agricultural and Biological Sciences.
- Environmental Science.
- Veterinary Science.
- Business, Management and Accounting.
- Social Sciences.
- Earth and Planetary Science.

1.8 **Areas of impact**. Overall, the subject-normalised impact of New Zealand publications between 2002 and 2006 has been slightly below the OECD average. Disciplines where New Zealand has an above average impact tend to be clustered in the medical sciences.

1.9 **Linkages**. 84% of New Zealand scientific publications during 2002-2007 involved multiple authors, 70% involved multiple institutions, and 44% involved multiple countries. In 2007, New Zealand researchers co-authored publications with authors from 125 countries. By far the most common international co-authoring occurred with co-authors from the United States, Australia and the United Kingdom. Other countries or regions that we collaborate with reasonably often include Canada, Germany, France, Japan, the Netherlands, Italy, South East Asia, China and Sweden.

1.10 **Tertiary Education Institutions**. For the set of New Zealand Tertiary Education institutions, the University of Auckland and the University of Otago recorded the highest publication output during the period 2002-2007. All major Tertiary Education institutions showed increasing publication impact during this period. In 2006 publications from six universities (Auckland, Otago, Victoria, Canterbury, Massey and Waikato) had a subject-normalised impact greater than the OECD average.

1.11 **Crown Research Institutes**. For the set of New Zealand Crown Research Institutes (CRIs), the National Institute of Water & Atmospheric Research (NIWA), AgResearch and Landcare Research recorded the highest publication output during the period 2002-2007. They have three of the highest four publication impact of the CRIs. They are also the only CRIs to publish papers with a subject-normalised impact above the OECD average for at least four of the years between 2002 and 2006.

2. Introduction

2.1 This report presents a bibliometric analysis of New Zealand's scientific publications. The purpose of this report is to identify areas of focus and strength within New Zealand's research community, show patterns of linkage and collaboration, and compare New Zealand's science performance with the rest of the OECD.

2.2 Bibliometrics is the quantitative study of research publications. It can be used, along with other measures, such as measures of patenting and innovation activities, to:

- Gain an overview of a country's research output.
- Understand the subject distribution of a country's research effort.
- Estimate the impact of a country's publications by counting the number of times they are cited by other authors.
- Examine collaborative activity within a country and internationally.

2.3 Underpinning this approach are the assumptions that *the result of research activity is knowledge*, and that *this knowledge is expressed through publication*. Therefore, analysing the publication output of a particular nation, region or institution will provide a greater understanding of the nature of it's scientific activity. The number of peer-reviewed papers published is indicative of the amount of research activity; the subject areas and disciplines associated with those papers are indicative of the areas of specialisation of this research activity; and the number of citations that these papers attract is indicative of the impact of this research activity.

2.4 There are theoretical limitations and constraints to what bibliometric analysis can tell us. These include that:

- Publication is not the sole output of scientific activity. For example, rather than peer-reviewed publications, other knowledge transfer mechanisms such as intellectual property protection or commercial secrecy are likely to be outputs of potentially commercialisable scientific activity.
- Not all publications appear in bibliometric databases. Conference presentations and proceedings, books and other media, also play a significant role in communicating research findings.
- Citations are an indirect indicator of quality, not a direct measure of it.

2.5 This report is the fourth in a series of bibliometric reports commissioned by the Ministry of Research, Science and Technology (MoRST). Previous reports were:

- **A Bibliometric Profile of the New Zealand Science System (2001)**. This study analysed New Zealand publications between 1986 and 1996, looking for changes over the period.
- **National Bibliometric Report 1997-2001 (2002)**. This report was jointly commissioned by MoRST, the Foundation for Research, Science and Technology (the Foundation), the Health Research Council (HRC) and the Royal Society of New Zealand (RSNZ). It analysed New Zealand publications over the period 1997-2001.
- **National Bibliometric Report 2001-2004 (2005)**. This report analysed New Zealand publications between 2001 and 2004, looking for changes over the period.

2.6 Previous reports used data extracted from Thomson-ISI/Thomson-Reuters databases. Caution should be used when comparing findings from the current report with those of past years.

3. Methodology

3.1 A separate document is planned to be prepared, with a full technical description of the method used. This chapter sets out a simplified explanation of the method used.

3.2 The analysis presented in this report is based on a customised dataset extracted from the Scopus database by Elsevier. This dataset consists of all content in the Scopus database for 2002-2007, with at least one author with at least one address in the OECD, and all citations attracted by these records, as of June 2008.

3.3 Before analysis was conducted, the dataset was partially cleaned, with all New Zealand addressed publications subjected to de-duplication at the institutional level, during which each institution was assigned to a relevant industry sector.

3.4 Publications with authors from different sectors or countries are affiliated with both sectors and countries. For example, a paper with two authors - one from New Zealand, and one from Australia - would be counted as both a New Zealand publication and an Australian publication. This means, for example, that the sum of New Zealand publications by sector is greater than the total number of New Zealand publications, and that the sum of publications by country is greater than the total number of world publications.

3.5 For this study, the discipline and subject area classifications used are Elsevier's. Publications are classified based on which journal they appear in.

3.6 The dataset also has several known practical limitations and constraints:

- Incomplete attribution of author affiliation. An estimated 20% of items have no author affiliation.
- Certain disciplines are under-represented. Scopus has limited coverage of the social sciences, and very limited coverage of the humanities.
- Journals in languages other than English are under-represented in the data. Of particular relevance to New Zealand, there is no coverage of journals in Te Reo Māori.
- Consortia, such as Centres of Research Excellence, are under-represented in the data, as authors tend to use their primary institutional affiliation.
- Articles published in multidisciplinary journals are classified as multidisciplinary.

4. Publications

TOTAL PUBLICATIONS

4.1 For the years 2002-2007, Scopus recorded a total of 40,376 publications with at least one author affiliated to a New Zealand institution.

4.2 New Zealand authors were affiliated with 0.7% of all publications in the OECD, comparable to Norway or Portugal. New Zealand's share of publications is relatively stable, rising from 0.6% in 2002 to 0.8% in 2007 (see Table 1).

Table 1 Share of total OECD publications by country of author

	Year of publication						
Author's affiliation	2002	2003	2004	2005	2006	2007	Total
United States	37%	37%	35%	34%	34%	35%	35%
United Kingdom	10.0%	10.5%	10.7%	10.7%	10.9%	11.1%	10.7%
Japan	10.5%	10.7%	10.8%	10.7%	10.0%	9.3%	10.3%
Germany	9.4%	10.0%	10.2%	10.1%	9.7%	9.5%	9.8%
France	6.6%	7.0%	7.2%	7.1%	6.9%	7.0%	7.0%
Canada	4.8%	5.3%	5.6%	5.9%	5.8%	6.1%	5.6%
Italy	4.8%	5.3%	5.5%	5.5%	5.6%	5.8%	5.4%
Spain	3.6%	3.9%	4.1%	4.2%	4.4%	4.6%	4.1%
Australia	3.1%	3.4%	3.6%	3.7%	3.9%	4.0%	3.6%
Korea, Republic Of	2.3%	2.8%	3.2%	3.4%	3.6%	3.7%	3.2%
Netherlands	2.7%	3.0%	3.1%	3.2%	3.2%	3.2%	3.1%
Switzerland	1.8%	2.1%	2.3%	2.3%	2.3%	2.3%	2.2%
Sweden	2.0%	2.2%	2.2%	2.2%	2.1%	2.2%	2.1%
Poland	1.8%	2.0%	2.1%	2.1%	2.1%	1.9%	2.0%
Turkey	1.4%	1.6%	1.9%	1.9%	2.0%	2.1%	1.8%
Belgium	1.5%	1.7%	1.7%	1.8%	1.7%	1.8%	1.7%
Austria	1.0%	1.2%	1.2%	1.2%	1.2%	1.3%	1.2%
Denmark	1.0%	1.1%	1.2%	1.2%	1.1%	1.2%	1.1%
Finland	1.0%	1.1%	1.1%	1.1%	1.1%	1.1%	1.1%
Greece	0.8%	0.9%	1.0%	1.1%	1.2%	1.3%	1.1%
Mexico	0.8%	0.9%	0.9%	0.9%	1.0%	0.9%	0.9%
Czech Republic	0.7%	0.8%	0.9%	0.9%	0.9%	0.9%	0.9%
Norway	0.7%	0.8%	0.8%	0.9%	0.9%	1.0%	0.8%
New Zealand	0.6%	0.7%	0.7%	0.8%	0.8%	0.8%	0.7%
Portugal	0.5%	0.6%	0.7%	0.7%	0.8%	0.8%	0.7%
Hungary	0.6%	0.6%	0.6%	0.7%	0.6%	0.6%	0.6%
Ireland	0.4%	0.5%	0.6%	0.6%	0.6%	0.7%	0.6%
Slovakia	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%
Iceland	0.05%	0.05%	0.05%	0.06%	0.06%	0.06%	0.05%
Luxembourg	0.01%	0.02%	0.02%	0.02%	0.03%	0.03%	0.02%
Total OECD publications	833,716	887,941	907,274	985,977	1,025,644	995,015	5,635,567

Note - The sum of the parts may be greater than the total, because many publications have authors from more than one country.

DISTRIBUTION OF NEW ZEALAND PUBLICATIONS BY SECTOR

4.3 Of the 40,376 New Zealand publications over the period 2002-2007, 28,745 (72%) have at least one author affiliated to a Tertiary Education institution. CRIs, district health boards (DHBs), and private firms make a smaller contribution to New Zealand's total publication output (see Table 2).

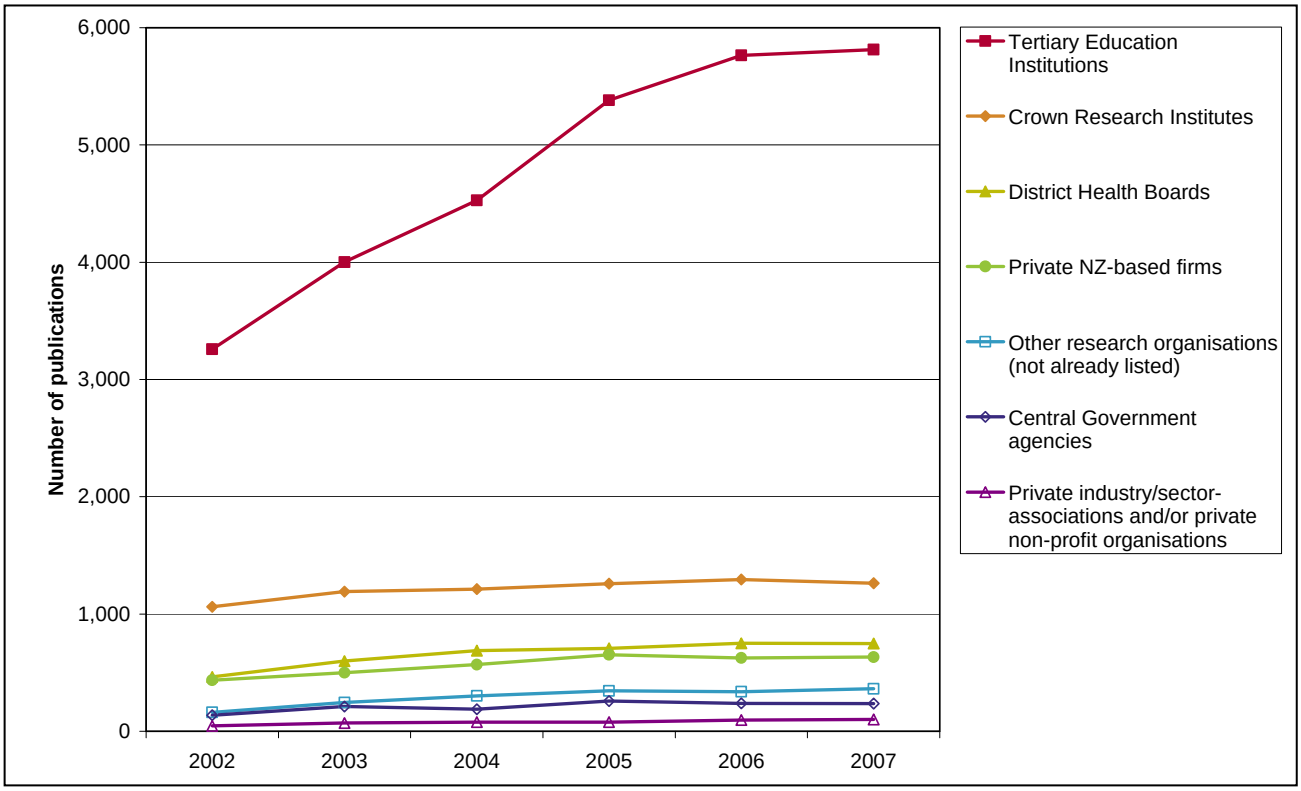
Table 2 Publication output by sector 2002-2007

Organisation type	Number of items 2002-2007	Percentage of Total
Tertiary Education Institutions	28,745	71.2%
Crown Research Institutes	7,281	18.0%
District Health Boards	3,957	9.8%
Private NZ-based firms	3,415	8.5%
Central Government agencies	1,270	3.1%
Uncategorised	833	2.1%
Other research organisations (not already listed)	537	1.3%
Private industry/sector-associations and/or private non-profit organisations	474	1.2%
Local/Regional Government	247	0.6%
Community and/or voluntary groups	114	0.3%
Total New Zealand publications	40,376	

Note – The sum of the parts may be greater than the total, because many publications have authors from more than one sector.

4.4 All research sectors have increased their publication output over the period 2002–2007. However, the most significant increase in both absolute and relative terms is seen in the Tertiary Education institutions (see Figure 1). Annual publication output within this sector went from 3,258 in 2002, to 5,813 in 2007, an increase of 78%.

Figure 1 Publication output of New Zealand researchers by sector affiliation of author 2002–2007

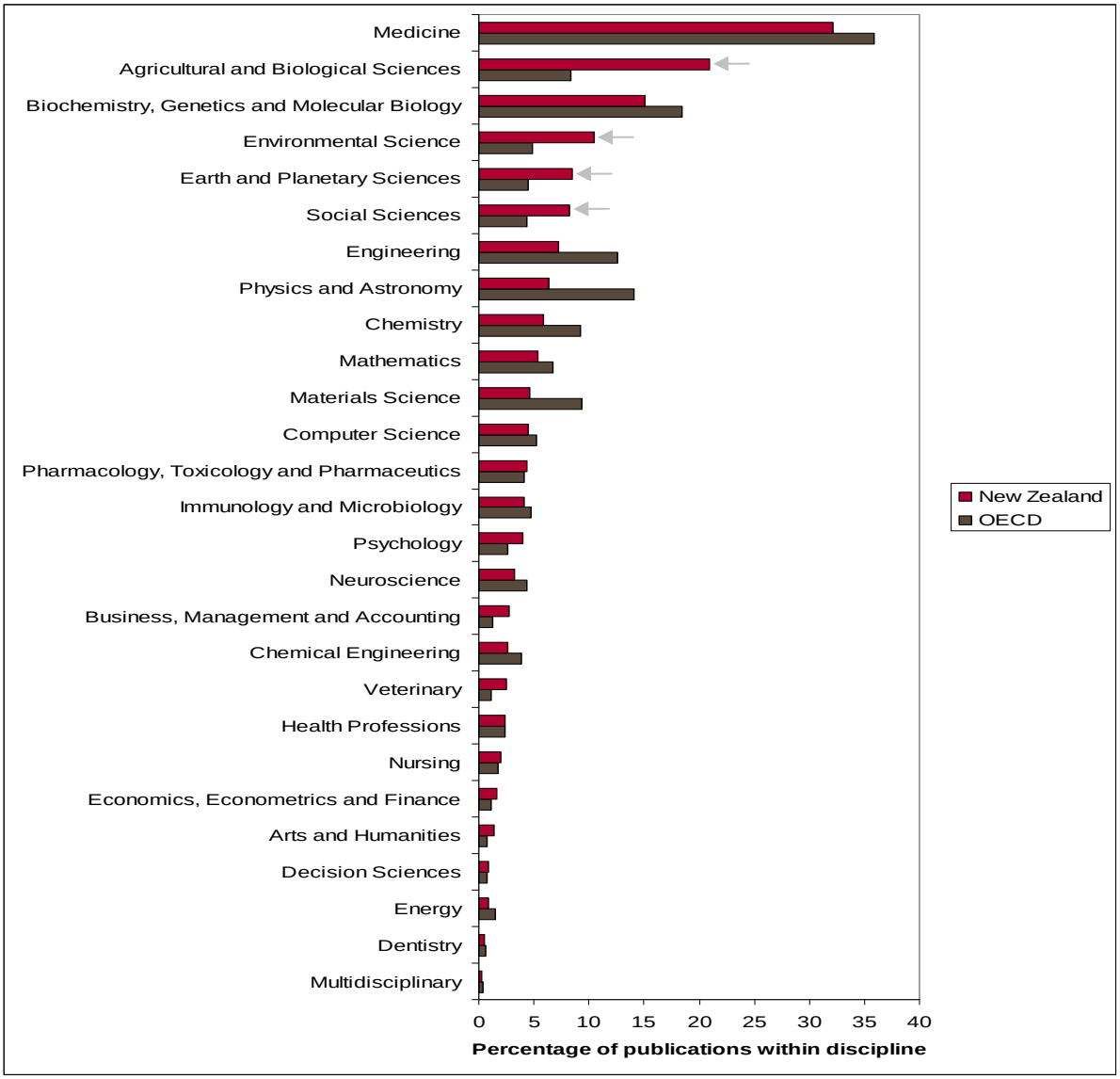


DISTRIBUTION OF NEW ZEALAND PUBLICATIONS BY SUBJECT-AREA

4.5 Most New Zealand-authored publications were in the fields of Medicine (33% of total New Zealand publications), Agricultural and Biological Sciences (21%), Biochemistry, Genetics and Molecular Biology (15%) and Environmental Science (11%).

4.6 Across the entire OECD, most publications were in the fields of Medicine (36% of total OECD publications), Biochemistry, Genetics and Molecular Biology (18%), Physics and Astronomy (14%), and Engineering (13%). Agricultural and Biological Sciences, and Environmental Science, are far less prominent in the OECD as a whole than in New Zealand, respectively making up only 8.4% and 4.8% of total OECD publications. Figure 2 shows the relative composition of New Zealand publications and OECD total publications by subject field.

Figure 2 Proportion of total New Zealand and OECD authored publications by field of study 2002-2007



4.7 Another way of looking at publication output data is a Subject Specialisation Index (SSI). The SSI in Figure 3 profiles New Zealand's international subject specialisation, i.e. where New Zealand publishes at a higher, equal or lower proportionate rate relative to the average OECD publication rate, for each particular subject area, and year of publication.

4.8 For instance, New Zealand is most specialised, publishes at a higher rate relative than the OECD as a whole, in the agricultural and biological sciences; environmental science; veterinary; business, management and accounting; earth and planetary sciences; etcetera. And New Zealand is least specialised, publishes as a lower relative rate than the OECD as a whole, in physics and astronomy; materials science; engineering; energy; chemistry; etcetera.

4.9 As can be seen in Figure 3, the profile of New Zealand's subject specialisation has remained relatively stable over time during 2002-2007.

SUBJECT AREA SPECIALISATION OF NEW ZEALAND RESEARCH SECTORS

4.10 Publication output data also allows us to determine the relative subject specialisation of New Zealand research, within New Zealand, by sector. Figure 4 presents the SSI of each of New Zealand's five largest research sectors (Tertiary Education, CRIs, central government, DHBs and private firms), relative to the remainder of New Zealand publications. SSIs for individual universities and CRIs are also available in chapter seven.

Figure 3 Subject Specialisation Index for New Zealand relative to total OECD

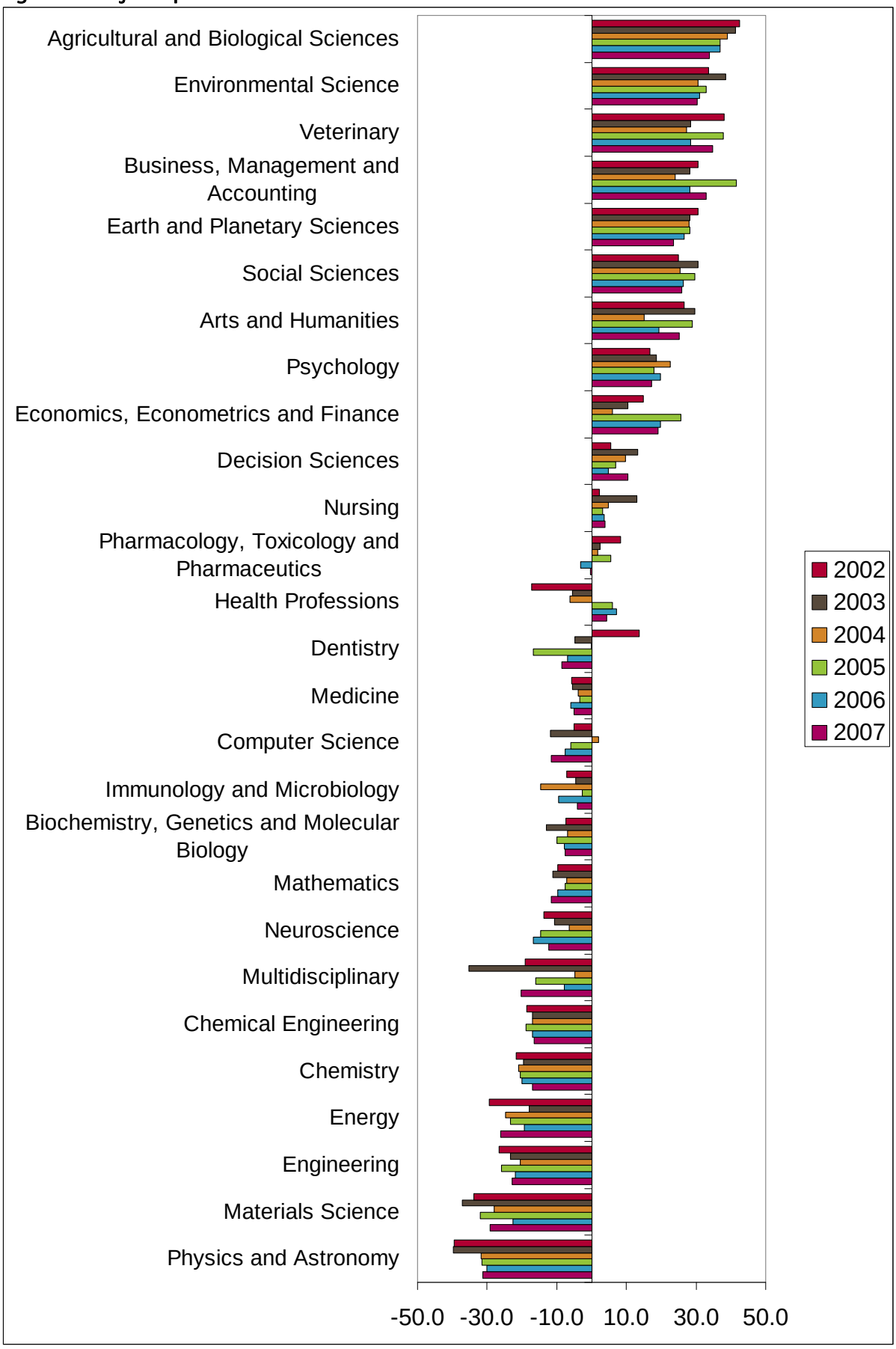
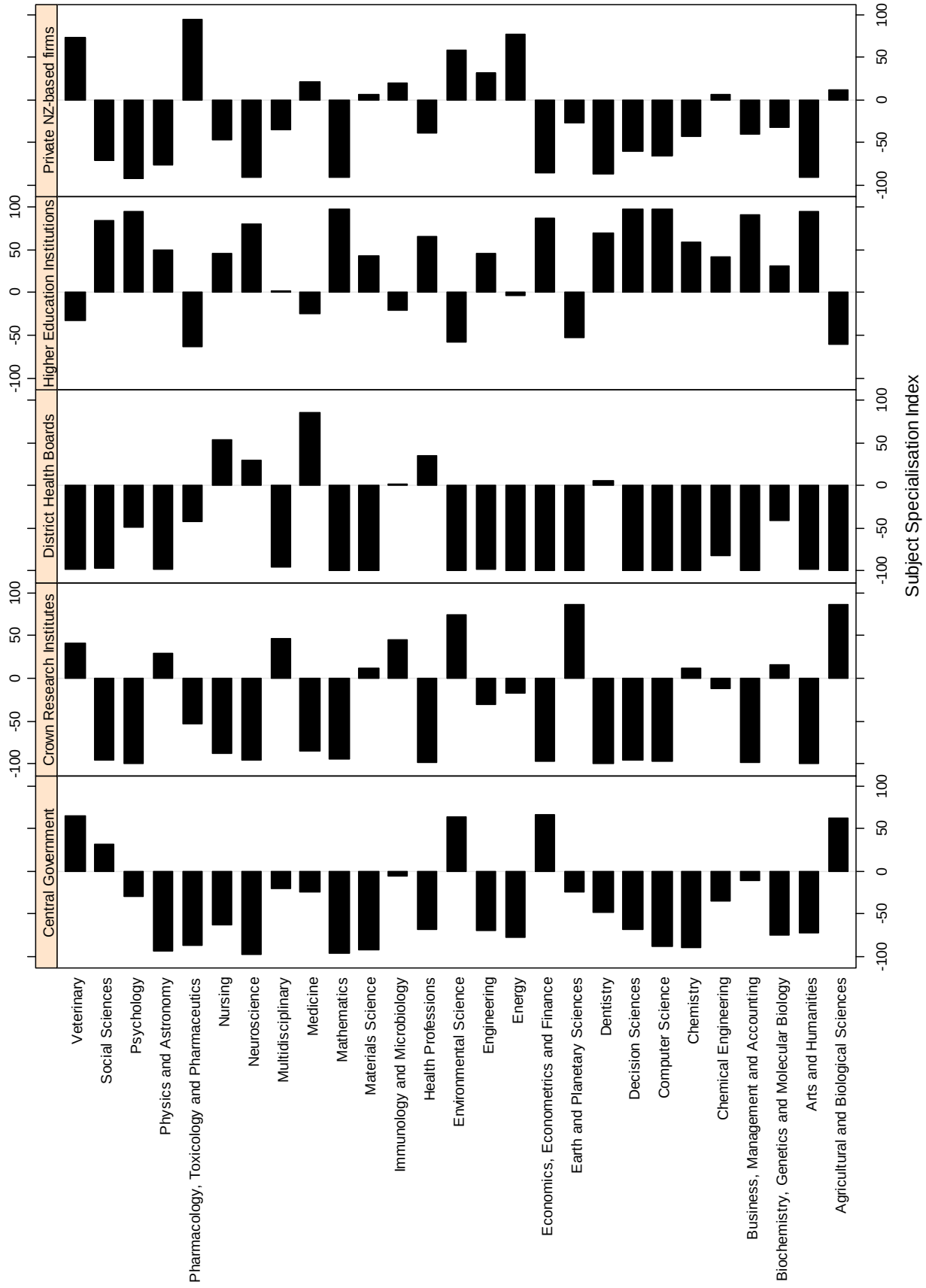


Figure 4 Subject specialisation index for New Zealand research sectors relative to the remainder of New Zealand publications, 2002–2007



4.11 As might be expected, Tertiary Education institutions have the broadest range of relative subject specialisations. There are 18 subjects where Tertiary Education institutions produce a greater proportion of research publications than New Zealand as a whole, and two (multidisciplinary and energy) where they are about the same. In addition, there are six subjects where only the Tertiary Education sector shows relative subject specialisation in New Zealand: psychology; mathematics; decision sciences; computer science; business, management, and accounting; and arts and humanities.

4.12 The CRIs specialise in a smaller yet nevertheless diverse range of topics, reflecting the areas of focus each CRI has. Over the entire sector, the strongest evidence of relative subject specialisation for CRIs is in three subjects: agricultural and biological sciences; environmental science; and earth and planetary sciences.

4.13 Central government research publications tend to be focused around five main subjects: veterinary; social science; environmental science; economics, econometrics and finance; and agriculture and biological sciences.

4.14 Private firm publications tend to be in the areas of: veterinary; pharmacology, toxicology and pharmaceuticals; energy; and environmental science. In two of those areas, no other sector shows specialisation: pharmacology, toxicology and pharmaceuticals; and energy.

4.15 District health boards show the narrowest relative subject specialisation of any sector. The areas of focus for DHBs are medicine; nursing; health professions; neuroscience; and to a lesser extent, immunology and microbiology; and dentistry. In the remaining subject areas, DHBs contribute little or no publication.

5. Scientific Productivity

5.1 For the years 2002-2007, New Zealand published an average of 1.51 publications per 1,000 population. On this measure of scientific productivity, New Zealand ranks 11th in the OECD, just behind the United Kingdom, Australia and Canada (see Table 3).

5.2 Over this period, New Zealand showed an increasing number of publications per capita, from 1.20 per 1,000 population in 2002, to 1.76 per 1,000 population in 2006. This is consistent with other OECD countries, most of which showed increased publications per capita per year from 2002 to 2007.

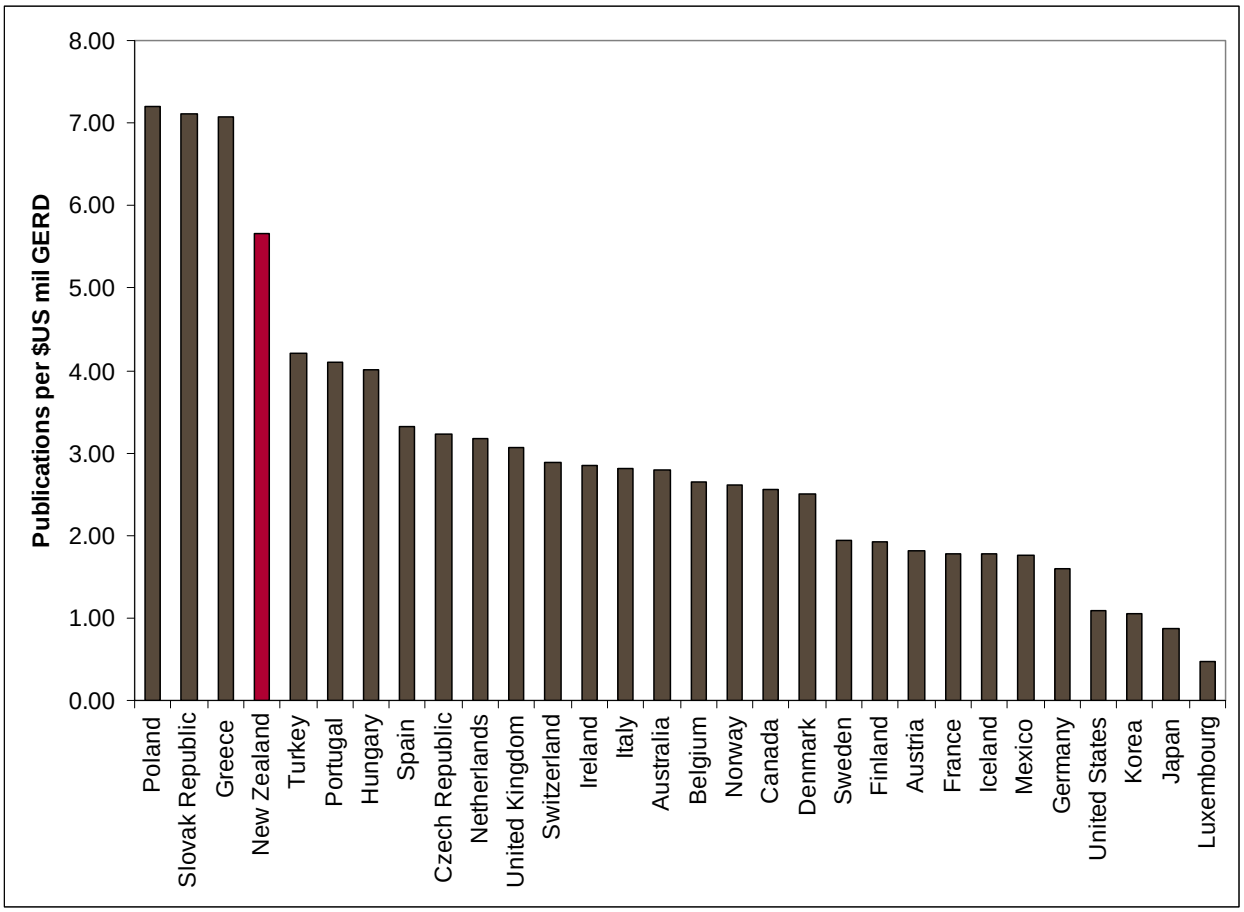
Table 3 Publications per 1,000 population 2002-2007[1]

	Year of publication						
Country	2002	2003	2004	2005	2006	2007	Mean
Switzerland	2.02	2.47	2.69	2.88	3.04	2.89	2.67
Sweden	1.80	2.08	2.16	2.31	2.32	2.26	2.16
Finland	1.56	1.78	1.91	2.03	2.09	2.04	1.90
Denmark	1.55	1.81	1.90	2.03	2.04	2.03	1.89
Netherlands	1.35	1.55	1.67	1.84	1.90	1.84	1.69
Iceland	1.39	1.51	1.52	1.82	1.86	1.88	1.66
Norway	1.27	1.45	1.57	1.82	1.88	1.93	1.65
United Kingdom	1.29	1.43	1.50	1.61	1.68	1.66	1.53
Australia	1.25	1.41	1.53	1.66	1.78	n/a	1.53
Canada	1.21	1.41	1.52	1.70	1.75	n/a	1.52
New Zealand	1.20	1.39	1.50	1.68	1.76	n/a	1.51
Belgium	1.14	1.36	1.43	1.59	1.60	1.59	1.45
Austria	1.02	1.23	1.30	1.39	1.38	1.41	1.29
Ireland	0.85	0.97	1.19	1.39	1.42	n/a	1.16
Germany	0.91	1.03	1.08	1.16	1.15	1.09	1.07
United States	1.01	1.07	1.02	1.07	1.10	1.07	1.06
France	0.86	0.97	1.01	1.08	1.08	1.03	1.00
Greece	0.60	0.69	0.81	0.93	1.07	1.04	0.86
Spain	0.68	0.78	0.81	0.89	0.97	0.95	0.85
Italy	0.68	0.78	0.82	0.87	0.92	0.90	0.83
Czech Republic	0.60	0.72	0.77	0.82	0.91	n/a	0.77
Japan	0.68	0.73	0.75	0.81	0.79	n/a	0.75
Portugal	0.42	0.53	0.60	0.65	0.77	0.75	0.62
Korea	0.40	0.51	0.60	0.69	0.75	0.75	0.62
Hungary	0.47	0.53	0.55	0.63	0.64	0.60	0.57
Slovak Republic	0.42	0.48	0.52	0.51	0.56	n/a	0.50
Poland	0.38	0.45	0.48	0.53	0.56	0.48	0.48
Luxembourg	0.22	0.33	0.44	0.45	0.56	0.59	0.43
Turkey	0.16	0.19	0.22	0.25	0.27	n/a	0.22
Mexico	0.06	0.07	0.08	0.09	0.09	n/a	0.08

[1] *These figures were calculated using population data from the OECD Main Science and Technology Indicators 2008/2. Gaps in the table indicate countries where comparable population figures have not yet been published.*

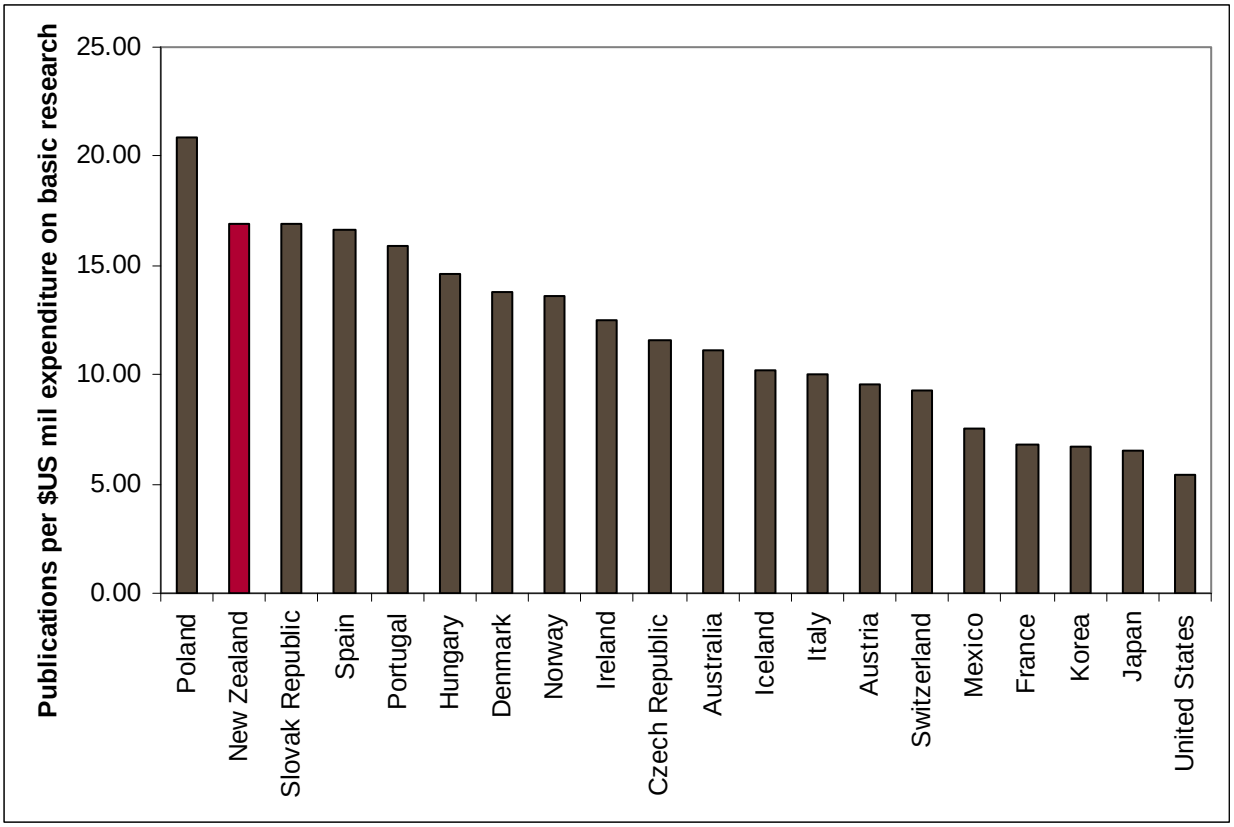
5.3 Another typical measure of scientific productivity is publications per dollar invested in research. New Zealand ranks very highly on this measure. For every $US million in gross expenditure on research and development (GERD), New Zealand produced an average of 5.66 publications between 2002 and 2007. Within this dataset, this is the fourth highest rate in the OECD (see Figure 5).

Figure 5 Publications per $US million GERD 2002-2007



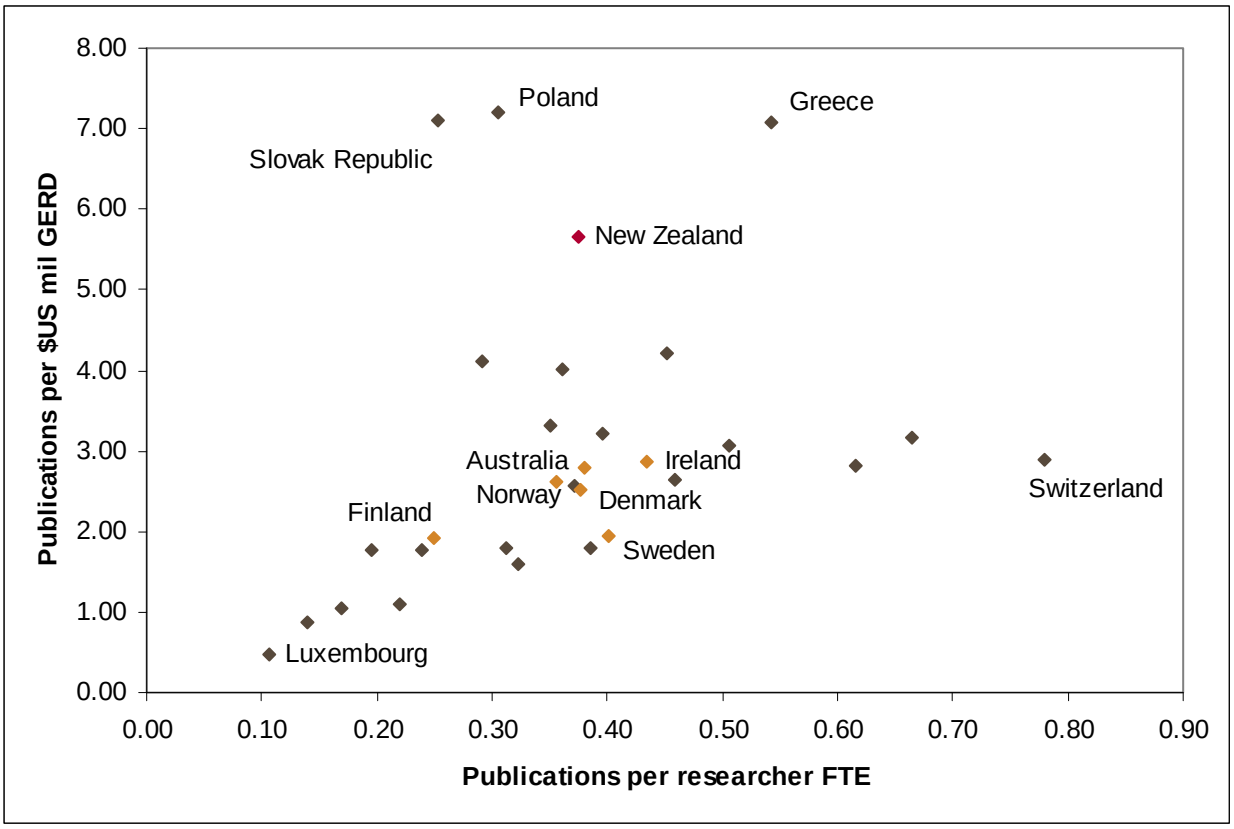
5.4 Since research publications are considered to be primarily outputs of basic research, publications per dollar invested in basic research is considered to be another and more accurate indication of scientific productivity. Again, New Zealand ranks very highly on this measure. Between 2002 and 2007, for every $US million spent on basic research, New Zealand produced an average of 16.91 publications. Within this dataset, this is the second highest rate in the OECD (see Figure 6).

Figure 6 Publications per $US million basic research 2002-2007



5.5 Figure 7 confirms New Zealand is an outlier in terms of its scientific publication productivity. New Zealand researchers publish at roughly the same rate as researchers in countries like Australia, Ireland, Denmark and Sweden; and at a greater rate than Finnish researchers. However, New Zealand's publication output is significantly greater than would be expected, given the size of its gross expenditure on research and development (GERD). When looking at scientific productivity in terms of publications per $US million of GERD, New Zealand is closer to the Slovak Republic, Poland and Greece, than to the countries we have recently normally aspired our science system to emulate, and compared our science system to (i.e. the Nordic countries, Ireland, and Australia, shown in orange in Figure 7).

Figure 7 Scientific productivity of OECD countries



6. Impact

6.1 Citation analysis is the most common method of measuring the impact of a particular paper. This chapter uses citations to identify areas of strength within New Zealand's research base.

6.2 A paper's citation frequency is strongly influenced by the discipline to which it belongs, and also by how many years it has been available to be cited. Within the Scopus database, for items published in 2002, mean citing frequencies vary over a scale from 44 cites per publication for multidisciplinary research to 1 cite per publication for architecture. Looking at research published in 2006, this variance is even wider in relative scale: a mean of 8.87 cites per publication for multidisciplinary compared to a minimum of 0.07 cites for emergency medical services. With mean citing frequency by discipline varying over a scale of 40–150 fold, crude comparisons of total citation counts reveal more about national or institutional disciplinary specialisation of research, than about the relative *impact strength* of that research.

6.3 To ensure robust impact comparisons can be made, this report uses subject-normalised citation impact.[2] Briefly, within this report, subject- or discipline-normalised impact is the mean citation rate for a set of publications, normalised by the expected number of citations received for all items in the same subject or discipline that were published in the same calendar year.

[2] A more complete technical definition of how citation rates are subject-normalised is planned to be given in the associated technical document.

CITATIONS PER PUBLICATION

6.4 Table 4 shows the subject-normalised impact of each OECD country's publications, relative to the rest of the OECD. Values higher than 1.00 signify that, on average, that country's publications have a higher than expected rate of citation; while values lower than 1.00 signify lower than expected citation rates. The subject-normalised impact of New Zealand publications between 2002 and 2006 is generally slightly below the OECD average.

Table 4 Subject-normalised impact of OECD publications

	Year of publication						Mean Relative
Country	2002	2003	2004	2005	2006	Mean	Impact[3]
Switzerland	1.29	1.34	1.37	1.41	1.40	1.36	1.42
Iceland	1.32	1.41	1.34	1.33	1.24	1.33	1.47
Denmark	1.16	1.31	1.29	1.30	1.33	1.28	1.36
Netherlands	1.19	1.29	1.25	1.28	1.32	1.27	1.32
United States	1.25	1.27	1.28	1.25	1.25	1.26	1.35
Sweden	1.17	1.21	1.19	1.18	1.19	1.19	1.25
Belgium	1.09	1.16	1.17	1.25	1.27	1.19	1.18
United Kingdom	1.13	1.17	1.17	1.19	1.20	1.17	1.19
Norway	1.05	1.11	1.15	1.14	1.18	1.13	1.11
Finland	1.11	1.13	1.11	1.13	1.14	1.12	1.11
Canada	1.07	1.13	1.14	1.13	1.14	1.12	1.11
Germany	1.01	1.03	1.07	1.12	1.16	1.08	1.09
Austria	0.97	1.04	1.11	1.13	1.13	1.08	1.08
Australia	1.02	1.05	1.08	1.07	1.09	1.06	1.04
Ireland	0.97	1.06	1.00	1.14	1.08	1.05	1.01
France	0.95	0.99	1.00	1.02	1.05	1.00	1.00
Italy	0.95	0.97	1.01	1.05	1.03	1.00	1.02
New Zealand	0.93	0.99	0.95	0.99	1.08	0.99	0.92
Spain	0.86	0.89	0.94	0.95	0.95	0.92	0.91
Portugal	0.87	0.89	0.91	0.93	0.94	0.91	0.81
Greece	0.80	0.84	0.86	0.88	0.83	0.84	0.75
Luxembourg	0.55	0.87	0.92	1.00	0.79	0.83	0.87
Hungary	0.73	0.82	0.84	0.82	0.83	0.81	0.82
Japan	0.77	0.78	0.80	0.78	0.78	0.78	0.77
Korea, Republic Of	0.79	0.78	0.77	0.74	0.67	0.75	0.64
Czech Republic	0.58	0.64	0.68	0.71	0.77	0.68	0.63
Mexico	0.62	0.63	0.69	0.65	0.63	0.64	0.59
Poland	0.53	0.58	0.62	0.60	0.62	0.59	0.54
Slovakia	0.48	0.54	0.58	0.59	0.66	0.57	0.53
Turkey	0.56	0.55	0.58	0.56	0.55	0.56	0.47

[3] *Mean relative impact is the subject-normalised citation rate, compared to the OECD average.*

IMPACT BY SUBJECT-AREA AND DISCIPLINE

6.5 Table 5 shows the impact of New Zealand publications categorised into 27 subject areas, relative to the rest of the OECD.

Table 5 Impact of New Zealand publications by subject area relative to the OECD

	Year of publication					
	2002	2003	2004	2005	2006	Mean
Veterinary	1.09	1.70	1.28	1.27	1.50	1.37
Nursing	1.13	1.24	1.13	1.22	1.30	1.20
Health Professions	0.83	0.90	0.80	0.82	1.95	1.06
Physics and Astronomy	1.00	1.01	1.05	1.09	1.09	1.05
Pharmacology, Toxicology and Pharmaceutics	0.96	1.22	1.00	0.92	1.02	1.02
Environmental Science	1.03	0.93	1.06	0.99	1.10	1.02
Medicine	0.92	1.07	0.99	1.01	0.99	1.00
Earth and Planetary Sciences	1.07	0.84	0.95	0.86	1.21	0.99
Multidisciplinary	0.70	1.00	1.20	0.96	1.04	0.98
Business, Management and Accounting	0.96	0.84	1.15	1.13	0.81	0.98
Mathematics	0.96	1.20	0.76	0.94	1.01	0.98
Arts and Humanities	0.79	0.98	0.80	1.10	1.13	0.96
Agricultural and Biological Sciences	0.90	0.90	0.97	0.91	1.14	0.96
Psychology	1.10	1.09	0.91	0.77	0.92	0.96
Social Sciences	1.04	0.91	0.91	0.94	0.95	0.95
Immunology and Microbiology	0.95	0.97	0.96	0.91	0.89	0.94
Computer Science	0.90	1.38	0.77	0.72	0.82	0.92
Engineering	0.92	0.96	0.89	0.93	0.88	0.92
Decision Sciences	0.56	1.15	1.06	0.76	0.92	0.89
Chemistry	0.75	0.85	0.88	0.96	0.88	0.86
Materials Science	0.85	0.81	0.86	0.95	0.80	0.85
Neuroscience	0.70	0.89	0.79	0.92	0.90	0.84
Economics, Econometrics and Finance	0.76	0.83	0.81	0.86	0.75	0.80
Biochemistry, Genetics and Molecular Biology	0.73	0.72	0.75	0.82	0.85	0.78
Energy	0.83	0.79	0.94	0.77	0.51	0.77
Dentistry	0.82	0.67	0.80	0.66	0.81	0.75
Chemical Engineering	0.61	0.81	0.75	0.57	0.75	0.70

6.6 For 2002-2006, there are two subject areas where New Zealand research has comparatively strong impact (veterinary and nursing), several subject areas where New Zealand performs at or about the OECD average, and several subject areas where New Zealand performs below the OECD average for impact.

6.7 Subject areas provide a broad view of national research productivity and impact. Scopus also has a more detailed approach available, being categorisation of publications into 334 sub-disciplines. As subject areas are simply group aggregates of disciplines, particular performance at the discipline level can be masked by the overall activity of other disciplines within a subject area.

6.8 Tables 6 and 7 present results by discipline, where New Zealand research impact has been consistently above, or below, the OECD average for those disciplines, respectively. Included disciplines have had a relative impact above, or below, the expected mean of 1.00 for at least four of the five years during 2002-2006, and consist of at least 100 publications during 2002-2006.

6.9 In some disciplines, New Zealand publications show a significantly higher impact than what would be expected for a average OECD publication in those disciplines.

6.10 While the impact of New Zealand medical publications in general tends to be at the OECD average (refer to Table 5), the impact of several medical disciplines is significantly higher. This includes health, toxicology and mutagenesis; pulmonary and respiratory medicine; toxicology; cardiology and cardiovascular medicine; paediatrics, perinatology and child health; obstetrics and gynaecology; nursing; medical pharmacology; and surgery.

6.11 A number of other individual disciplines in New Zealand also show significantly higher than average impact, including veterinary; palaeontology; building and construction; chemical engineering (miscellaneous); and law.

Table 6 High average impact New Zealand publications by discipline relative to the OECD

	2002	2003	2004	2005	2006	Mean
Health, Toxicology and Mutagenesis	1.73	1.65	1.76	1.36	1.63	1.63
Pulmonary and Respiratory Medicine	1.62	1.94	1.70	1.63	0.98	1.57
Toxicology	1.38	1.64	1.52	1.18	1.34	1.41
Cardiology and Cardiovascular Medicine	1.13	1.49	1.61	1.14	1.65	1.41
Veterinary (all)	1.09	1.51	1.38	1.30	1.63	1.38
Palaeontology	1.39	1.27	1.40	0.73	2.04	1.37
Paediatrics, Perinatology and Child Health	1.04	1.53	1.38	1.40	1.44	1.36
Obstetrics and Gynaecology	1.57	1.22	1.02	1.37	1.50	1.34
Building and Construction	1.41	1.46	0.65	1.93	1.18	1.33
Nursing (all)	1.00	1.37	1.08	1.50	1.65	1.32
Chemical Engineering (miscellaneous)	1.09	0.97	1.25	1.32	1.87	1.30
Pharmacology (medical)	1.34	1.53	1.19	0.96	1.30	1.26
Law	1.34	1.05	1.28	1.01	1.35	1.21
Surgery	0.89	1.20	1.45	1.44	1.01	1.20

Table 6 (continued)

	2002	2003	2004	2005	2006	Mean
Business, Management and Accounting (all)	1.33	1.12	0.89	1.54	1.02	1.18
Mathematics (all)	1.42	0.81	1.15	1.35	1.16	1.18
Ecology, Evolution, Behaviour and Systematics	1.24	1.02	1.23	1.07	1.32	1.17
Soil Science	1.16	1.15	1.11	1.00	1.39	1.16
Psychiatry and Mental Health	1.16	1.48	0.84	1.13	1.16	1.15
Ecology	1.25	1.02	1.08	1.22	1.16	1.15
Applied Microbiology and Biotechnology	1.19	1.05	1.24	1.15	1.03	1.13
Geophysics	1.21	0.93	1.02	1.17	1.31	1.13
Water Science and Technology	1.10	1.10	1.07	1.13	1.18	1.11
Parasitology	0.92	1.06	1.30	1.02	1.25	1.11
Geography, Planning and Development	1.20	1.11	1.14	1.06	1.04	1.11
Earth-Surface Processes	0.85	1.18	1.34	1.03	1.15	1.11
Anaesthesiology and Pain Medicine	1.23	1.30	1.05	1.07	0.76	1.08
Rehabilitation	0.99	1.08	1.05	1.09	1.19	1.08
Forestry	1.03	1.26	1.06	0.80	1.25	1.08
Atomic and Molecular Physics, and Optics	1.06	1.11	0.85	1.20	1.04	1.05

Table 7 Low average impact New Zealand publications by discipline relative to the OECD

	2002	2003	2004	2005	2006	Mean
Physics and Astronomy (all)	0.62	0.98	0.92	0.98	1.38	0.98
Microbiology	1.03	0.97	0.99	0.91	0.91	0.96
Biotechnology	0.91	1.08	0.94	0.96	0.89	0.96
Mathematical Physics	0.91	0.92	0.65	1.48	0.71	0.94
Computer Science (all)	0.75	0.75	0.92	0.98	1.26	0.93
Medicine (all)	0.84	0.94	0.86	1.03	0.94	0.92
Haematology	1.64	0.98	0.85	0.67	0.46	0.92
Computational Theory and Mathematics	0.71	1.46	0.88	0.61	0.94	0.92
Economics and Econometrics	0.78	0.91	0.95	1.10	0.85	0.92
Oceanography	0.97	0.80	0.88	0.77	1.15	0.91
Space and Planetary Science	0.99	0.78	0.97	0.94	0.88	0.91
Environmental Chemistry	0.78	0.96	1.09	0.77	0.93	0.90
Molecular Biology	0.89	0.77	0.77	1.02	0.99	0.89
Management Science and Operations Research	0.70	0.89	0.90	0.98	0.93	0.88
Management, Monitoring, Policy, Law	0.86	0.90	1.14	0.69	0.82	0.88
Environmental Engineering	0.76	0.84	0.97	0.78	1.04	0.88
Physical and Theoretical Chemistry	0.73	0.73	0.94	0.93	1.04	0.87
Pharmaceutical Science	0.82	0.66	0.84	1.21	0.83	0.87
Earth and Planetary Sciences (miscellaneous)	1.00	0.79	0.70	0.80	1.07	0.87
Biochemistry	0.75	0.81	0.87	0.92	0.98	0.87
Discrete Mathematics, Combinatorics	0.80	0.72	0.71	1.28	0.82	0.87
Physical Therapy, Sports Therapy and Rehabilitation	0.67	0.97	0.91	0.86	0.91	0.86
Arts and Humanities (all)	0.75	0.90	0.69	0.95	1.01	0.86
Spectroscopy	0.60	0.66	1.34	0.84	0.86	0.86

Table 7 (continued)

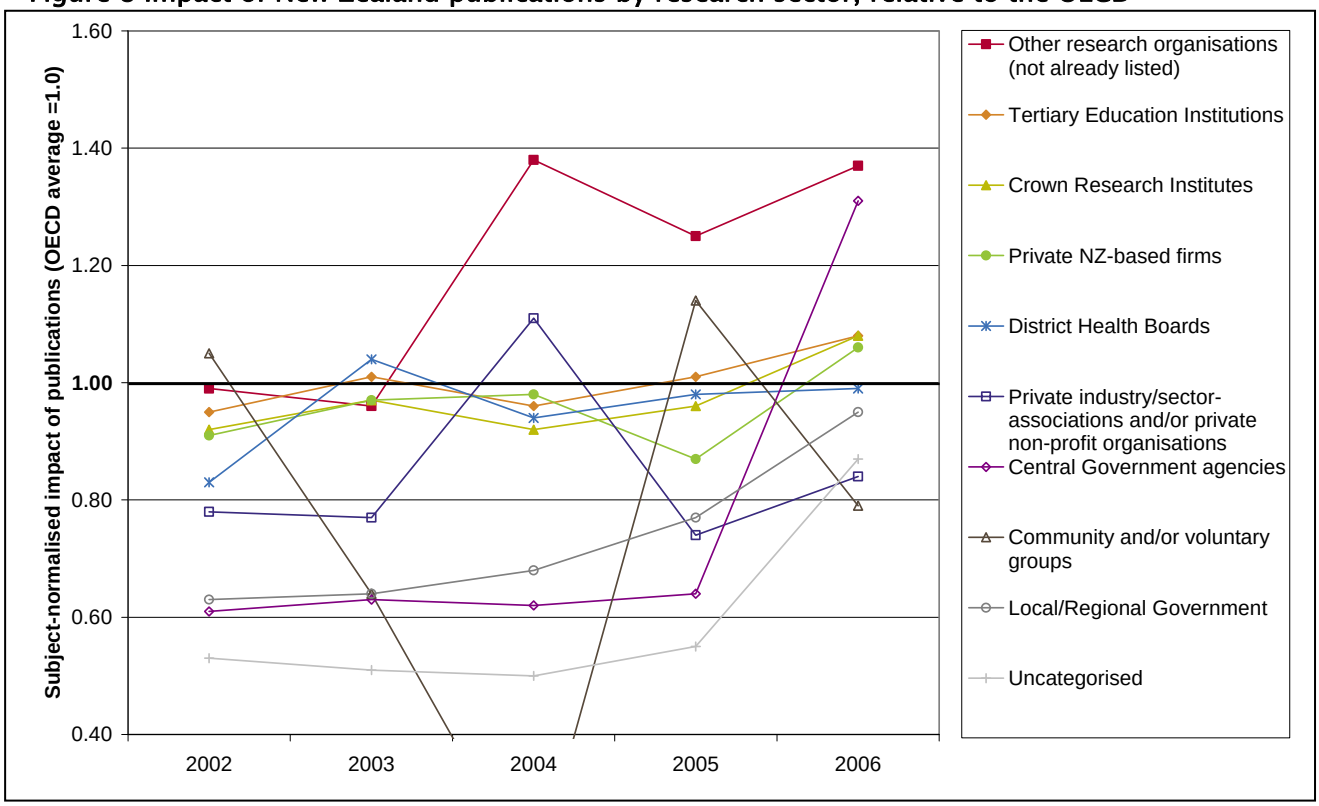
	2002	2003	2004	2005	2006	Mean
Inorganic Chemistry	0.83	0.80	0.72	1.02	0.91	0.86
Marketing	0.79	0.96	1.05	0.96	0.52	0.85
Electrical and Electronic Engineering	1.05	0.80	0.92	0.82	0.68	0.85
Pharmacology	0.74	1.07	0.74	0.75	0.94	0.85
Cell Biology	0.87	0.70	0.76	1.02	0.90	0.85
Plant Science	0.73	0.78	0.85	0.81	1.08	0.85
Cellular and Molecular Neuroscience	0.56	0.86	0.68	0.93	1.15	0.84
Clinical Biochemistry	0.62	1.05	0.87	0.70	0.93	0.83
Physiology	0.85	0.74	0.87	0.72	0.96	0.83
Analytical Chemistry	0.87	0.70	0.78	0.89	0.90	0.83
Electronic, Optical and Magnetic Materials	0.97	0.75	0.97	0.92	0.50	0.82
Mechanics of Materials	0.83	1.01	0.62	0.92	0.73	0.82
Dentistry (all)	0.81	0.73	0.94	0.75	0.85	0.82
Radiology, Nuclear Medicine and Imaging	0.77	0.85	0.79	0.71	0.96	0.81
Materials Chemistry	0.97	0.87	0.77	0.76	0.69	0.81
Materials Science (miscellaneous)	0.77	0.87	0.91	0.67	0.82	0.81
Agricultural and Biological Sciences (all)	0.72	0.69	0.74	0.79	1.09	0.81
Education	0.94	0.91	0.75	0.68	0.71	0.80
Physics and Astronomy (miscellaneous)	0.50	0.58	1.09	0.94	0.85	0.79
Chemistry (all)	0.78	0.87	0.66	0.98	0.67	0.79
Nature and Landscape Conservation	0.94	0.72	0.89	0.62	0.77	0.79
Developmental Biology	0.79	0.72	0.99	0.66	0.78	0.79
Neuropsychology and Physiological Psychology	0.85	0.56	1.14	0.62	0.74	0.78
Neurology	0.57	1.08	0.52	0.75	0.96	0.78
Internal Medicine	1.06	0.46	0.72	0.62	0.98	0.77
Horticulture	0.92	0.57	0.81	0.74	0.64	0.73
Pathology and Forensic Medicine	0.75	0.73	0.81	0.50	0.81	0.72
Chemistry (miscellaneous)	0.56	0.77	0.74	0.75	0.78	0.72
Engineering (all)	0.43	1.03	0.71	0.94	0.49	0.72
Agricultural and Biological Sciences (miscellaneous)	0.56	0.72	0.76	0.72	0.80	0.71
Social Sciences (miscellaneous)	0.33	0.51	0.71	1.04	0.94	0.71
Critical Care and Intensive Care Medicine	1.37	0.43	0.79	0.81	0.09	0.70
Experimental and Cognitive Psychology	0.88	0.52	0.71	0.59	0.70	0.68
Library and Information Sciences	1.41	0.64	0.50	0.58	0.26	0.68
Biochemistry, Genetics and Molecular Biology (all)	0.63	0.75	0.49	0.76	0.72	0.67
Materials Science (all)	0.49	0.53	0.78	0.85	0.64	0.66
Behavioural Neuroscience	0.76	0.73	0.67	0.41	0.65	0.64
Structural Biology	0.85	0.34	1.00	0.54	0.47	0.64
Finance	0.80	0.69	0.56	0.74	0.36	0.63
Energy Engineering and Power Technology	0.75	0.59	0.80	0.65	0.35	0.63
Anatomy	0.66	0.38	0.43	0.56	0.61	0.53
Bioengineering	0.35	0.73	0.39	0.49	0.68	0.53
Colloid and Surface Chemistry	0.27	0.71	0.67	0.53	0.41	0.52

IMPACT BY SECTOR

6.12 Figure 8 sets out the subject-normalised impact of New Zealand publications, by sector-affiliation of author, relative to the OECD. Publications from Tertiary Education institutions, CRIs, DHBs and private firms are shown to be cited at about the OECD average by discipline and year.

6.13 The skewed nature of citation distribution entails that these figures are sensitive to outliers, regardless of the size of the sample. Sectors that are relatively small in size (such as other research organisations; central government agencies; local government; and community groups) are associated with greater potential error. Particular care should be taken with figures from these smaller sectors.

Figure 8 Impact of New Zealand publications by research sector, relative to the OECD



6.14 In general, more recent New Zealand publications appear to have increasing impact. Based on the dataset it is not possible to determine if this is due to the New Zealand publications having genuinely increased citation impact, or if this is due to them showing greater immediacy than the OECD mean. Nevertheless, the latter would be surprising.[4]

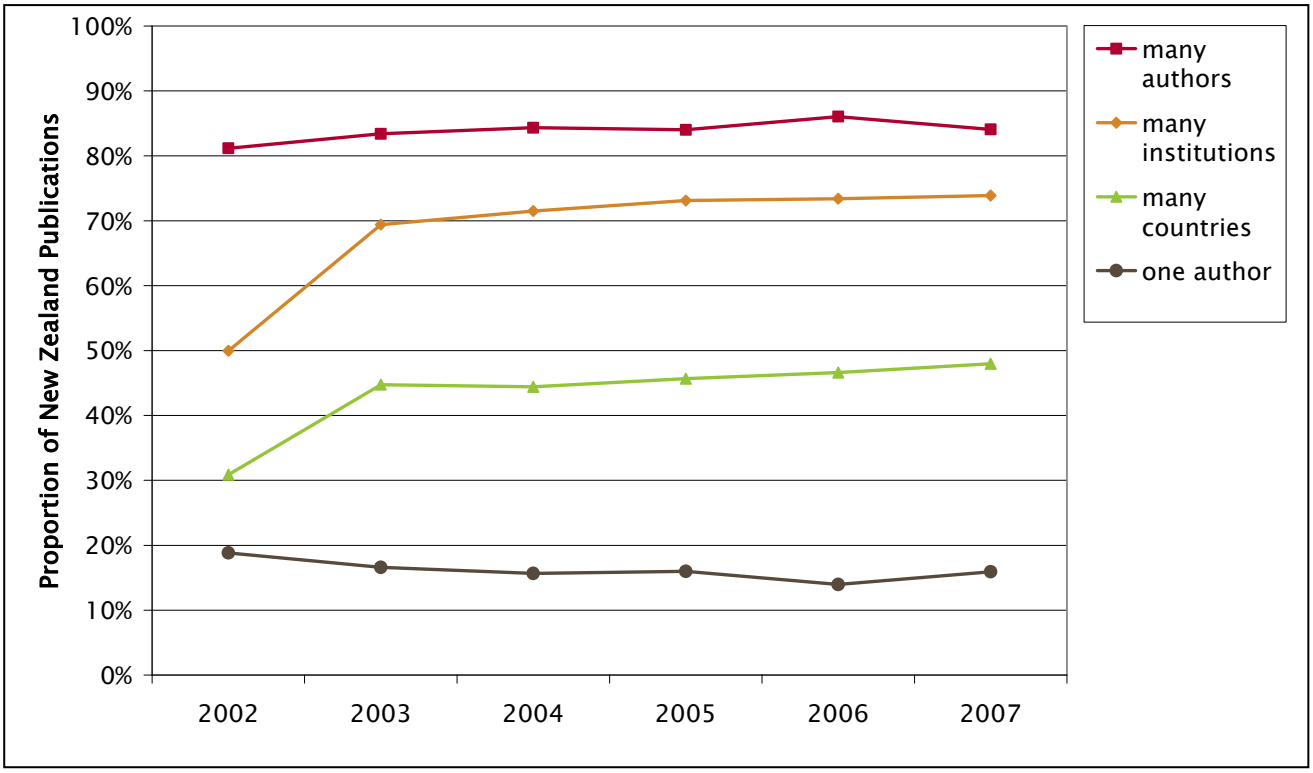
[4] Immediacy is a measure of how soon after publication citation occurs. Previous New Zealand bibliometric reports seem to have determined that New Zealand has similar or lower immediacy than the OECD mean.

7. Collaboration

7.1 This chapter presents information on patterns of collaboration. For the purposes of this study, collaboration occurs where a publication is affiliated to more than one author, more than one institution or more than one country.

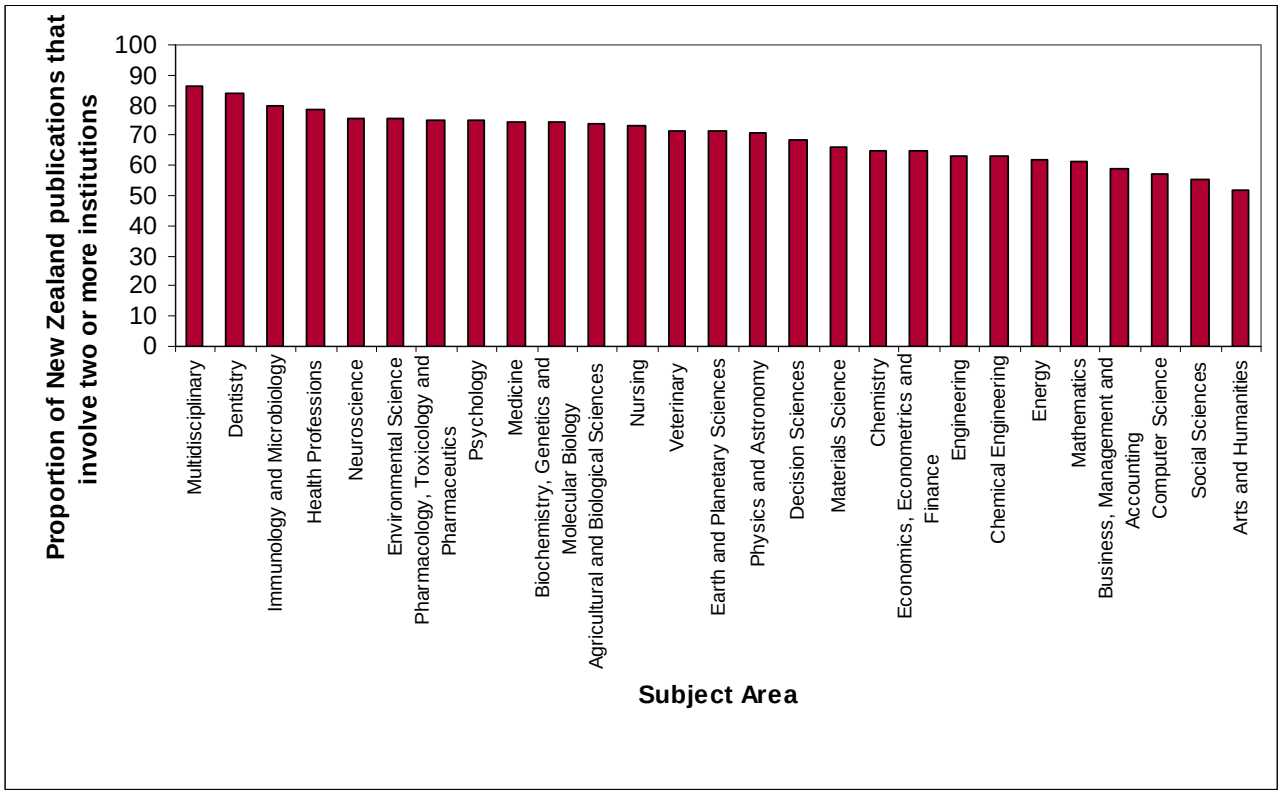
7.2 As shown in Figure 9, for each year from 2002 to 2007, over 80% of New Zealand scientific publications involved multiple authors, about 70% involved multiple institutions, and about 45% involved multiple countries. Less than 20% were sole author publications.

Figure 9 Proportion of all New Zealand-authored publications by type of collaboration 2002-2007



7.3 The subject areas showing the highest rates of institutional collaboration were multidisciplinary research, and the medical, biological and environmental sciences (see Figure 10). Publications in the Arts and Humanities and in the Social Sciences were least likely to exhibit collaboration at the institutional level.

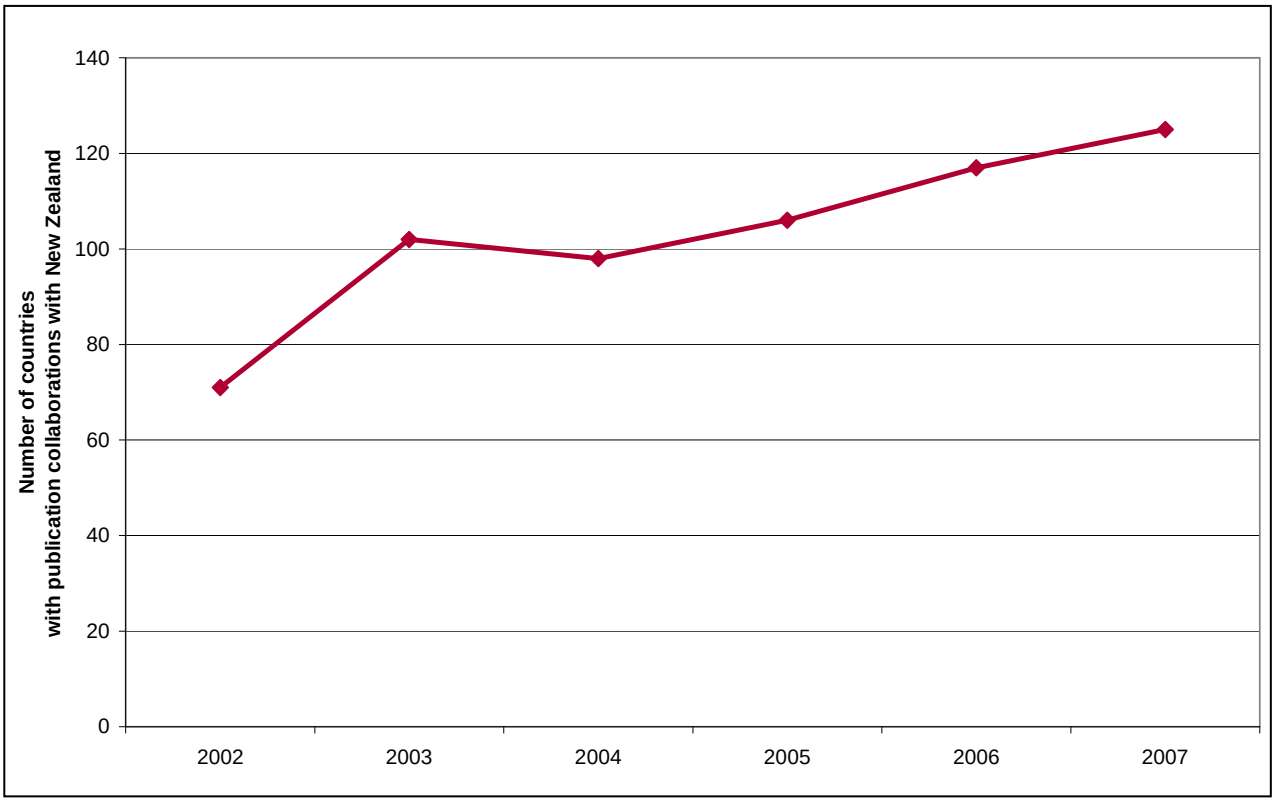
Figure 10 Proportion of New Zealand publications involving collaboration between institutions, by subject area



NEW ZEALAND INTERNATIONAL COLLABORATION

7.4 In 2007, New Zealand researchers co-authored publications with authors from 125 countries. The number of countries New Zealand collaborated with increased by 76% between 2002 and 2007 (see Figure 11).

Figure 11 Number of countries co-authoring publications with New Zealand authors



7.5 New Zealand is not alone in increasing the number of countries it collaborates with. All OECD countries appear to be increasingly diversifying the number of countries that their researchers work with. New Zealand ranks 19th in the OECD for number of countries collaborated with in 2007 (see Table 8).

Table 8 Number of countries co-authoring publications with an OECD country

	Year of publication					
Country	2002	2003	2004	2005	2006	2007
United States	181	196	193	201	202	202
United Kingdom	174	177	186	179	192	184
France	159	164	167	174	177	185
Germany	147	156	157	161	170	161
Canada	133	152	146	166	172	168
Australia	126	142	141	152	161	166
Italy	131	138	140	145	159	164
Netherlands	133	135	142	141	159	153
Switzerland	121	143	144	146	156	153
Japan	118	141	147	149	148	148
Belgium	123	133	138	142	147	154
Spain	111	128	128	139	152	146
Sweden	116	126	118	129	137	137
Denmark	104	128	117	118	134	136
Austria	99	108	112	107	132	120
Norway	95	100	109	113	128	132
Mexico	91	105	103	105	123	124
Finland	90	109	105	104	119	113
New Zealand	71	102	98	106	117	125
Poland	85	99	101	108	117	105
Korea	81	85	105	108	117	112
Portugal	80	96	102	105	108	110
Turkey	80	94	97	104	119	104
Czech Republic	71	89	95	101	117	106
Greece	78	82	98	89	118	101
Ireland	72	85	90	93	116	108
Hungary	74	82	82	92	90	99
Slovakia	57	78	87	82	100	89
Iceland	36	45	43	65	55	69
Luxembourg	26	44	50	41	53	57

7.6 Most of New Zealand's collaborations are with the United States, Australia, or the United Kingdom. There is a substantial drop-off to New Zealand's next largest research publication partners. Outside the OECD, New Zealand's most significant linkages are with China and South East Asia. (See Figures 12 and 12a.)

Figure 12 Percentage of international collaboration by region for all New Zealand publications

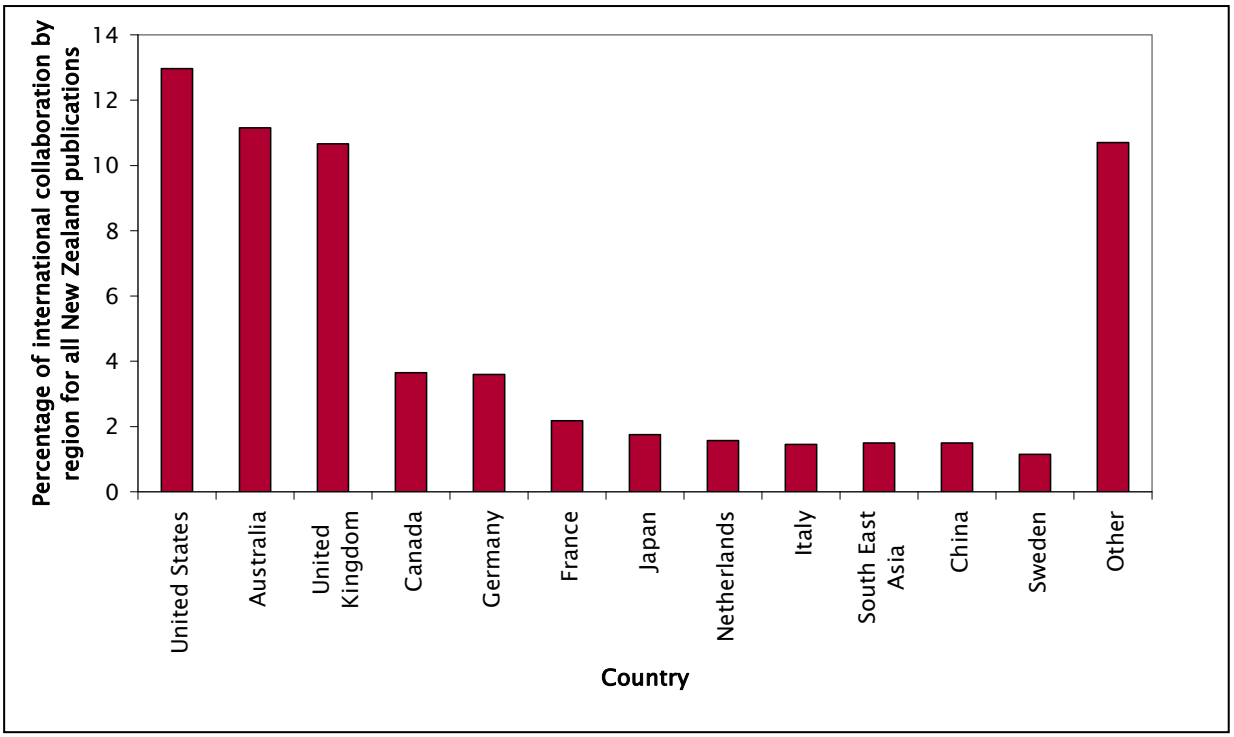
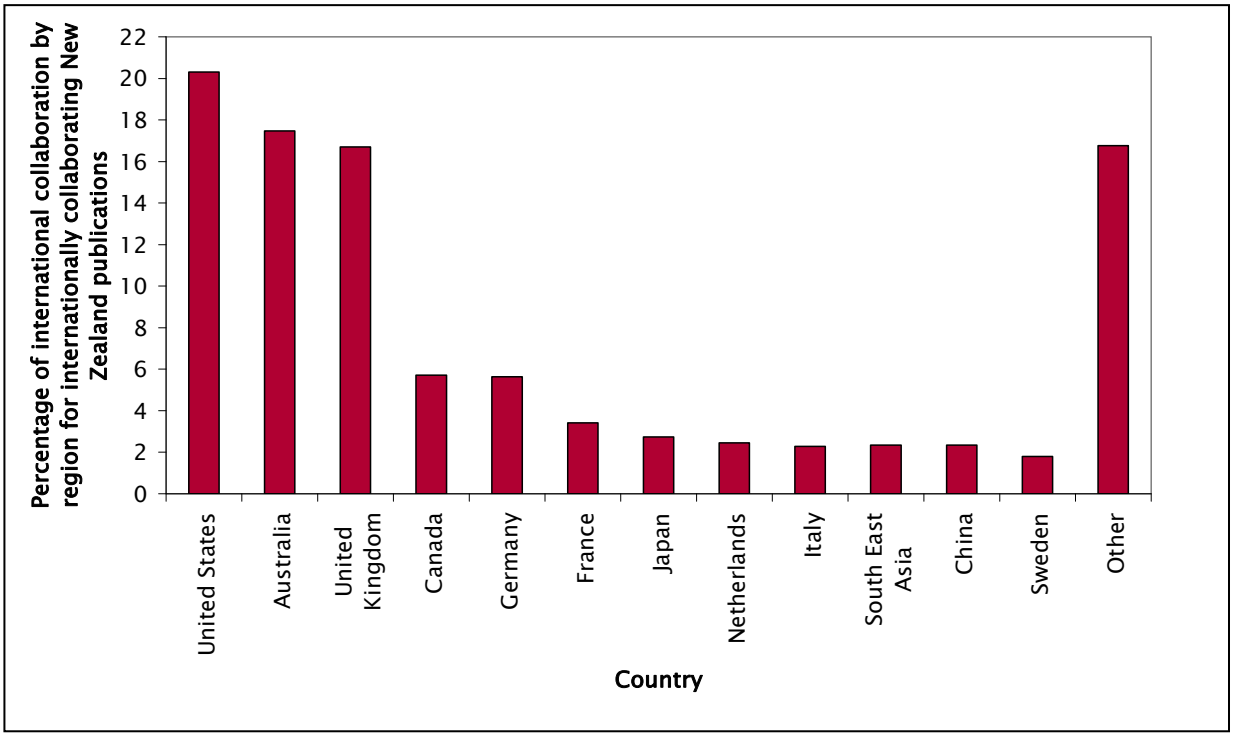


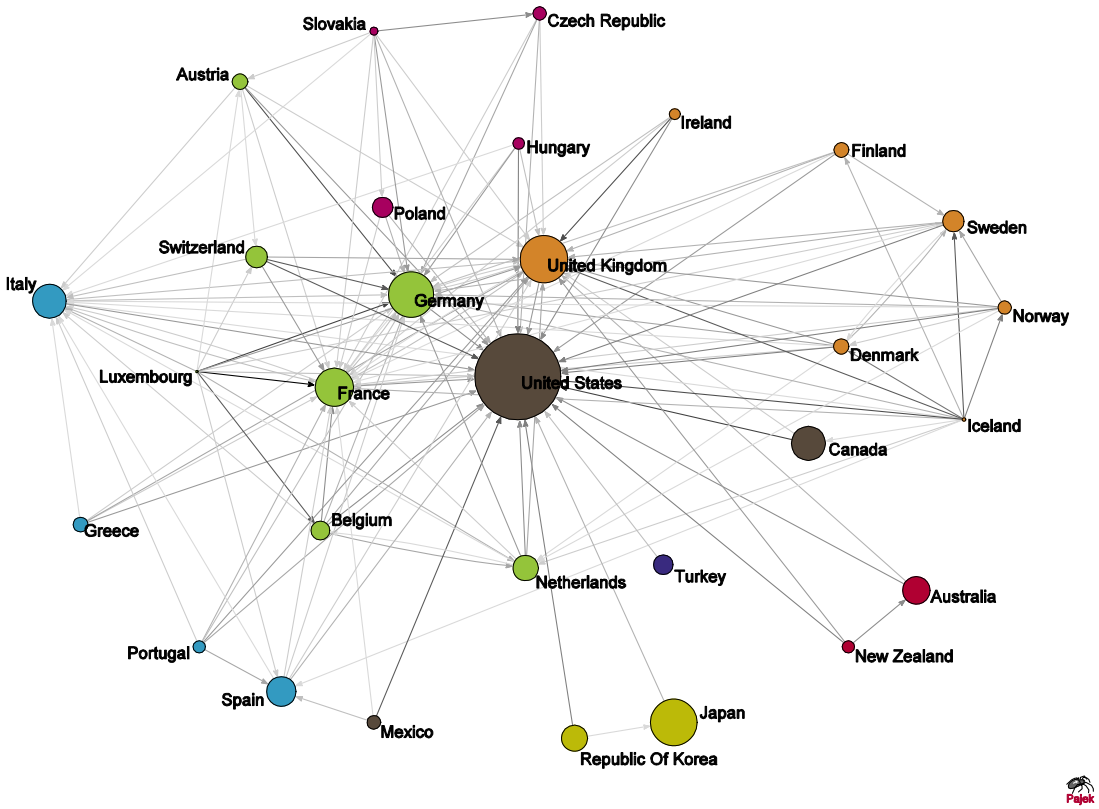
Figure 12a Percentage of international collaboration by region for all *internationally collaborating* New Zealand publications



NETWORKS OF INTERNATIONAL COLLABORATION

7.7 One way of visualising international publication collaboration is a network chart. Figure 13 is a network chart of collaborations between OECD countries. The ray lines in this figure represent publication collaboration where the proportion of publications involving the target country exceeds a threshold of 4% of that country's total publications. The thickness of the ray lines represent the percentage of publications involved. Country dots are coloured using arbitrary regional groupings, and each country's dot diameter is determined by the number of countries collaborating with it.

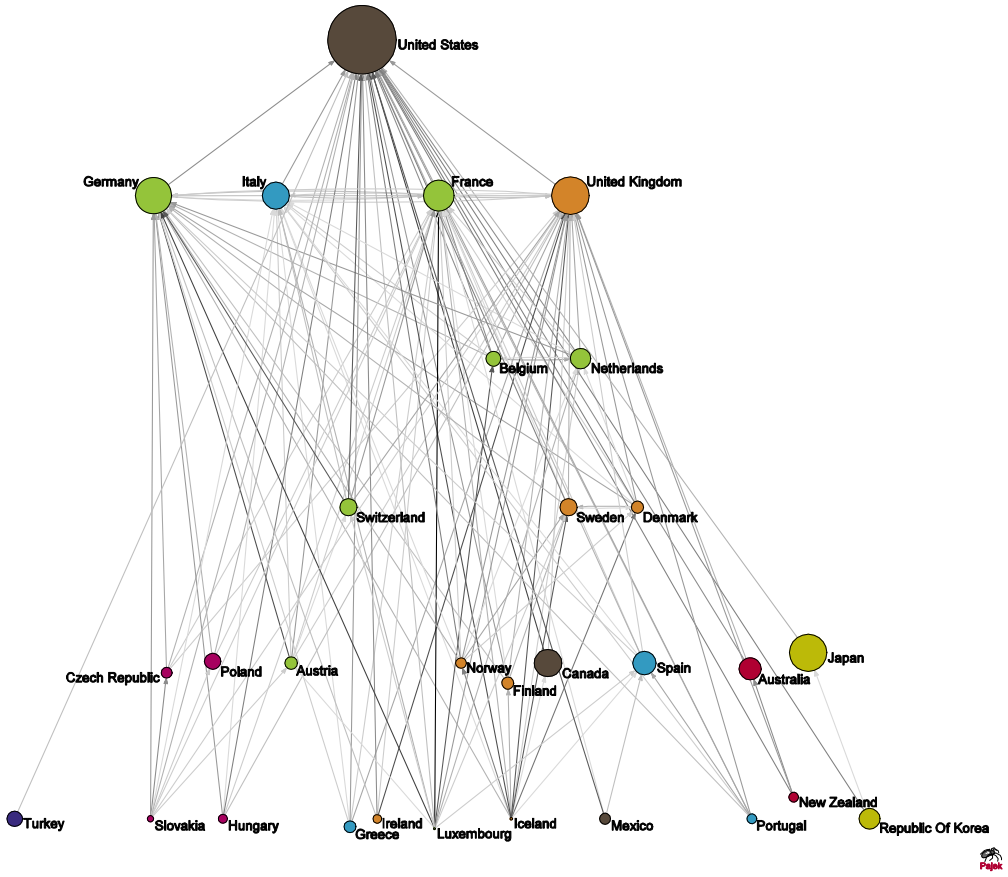
Figure 13 Proportion of OECD country publications co-authored with other OECD countries



7.8 Although relationships are largely asymmetric, there are exceptions. France's collaborations with Italy, Germany, and the United Kingdom comprise a significant proportion (greater than 4%) of these countries' total publications. The linkages between Germany and the United Kingdom, between Sweden and Denmark, and between Belgium and the Netherlands are also reciprocal. In general, both the number of other nations collaborating with a country, and the proportion of papers arising from collaboration, correlate with that latter country's publication output. (Although Luxembourg is a distinct outlier to this generalisation.)

7.9 The 4% threshold is arbitrary, but brings clarity to what is otherwise a very densely interconnected network. While it is granted that Figure 14 is an artefact of this threshold, the resulting rearranged network chart shows strong evidence that collaboration satisfies a 'ranked clusters' model.

Figure 14 Ranked clusters model, proportion of OECD country publications co-authored with other OECD countries

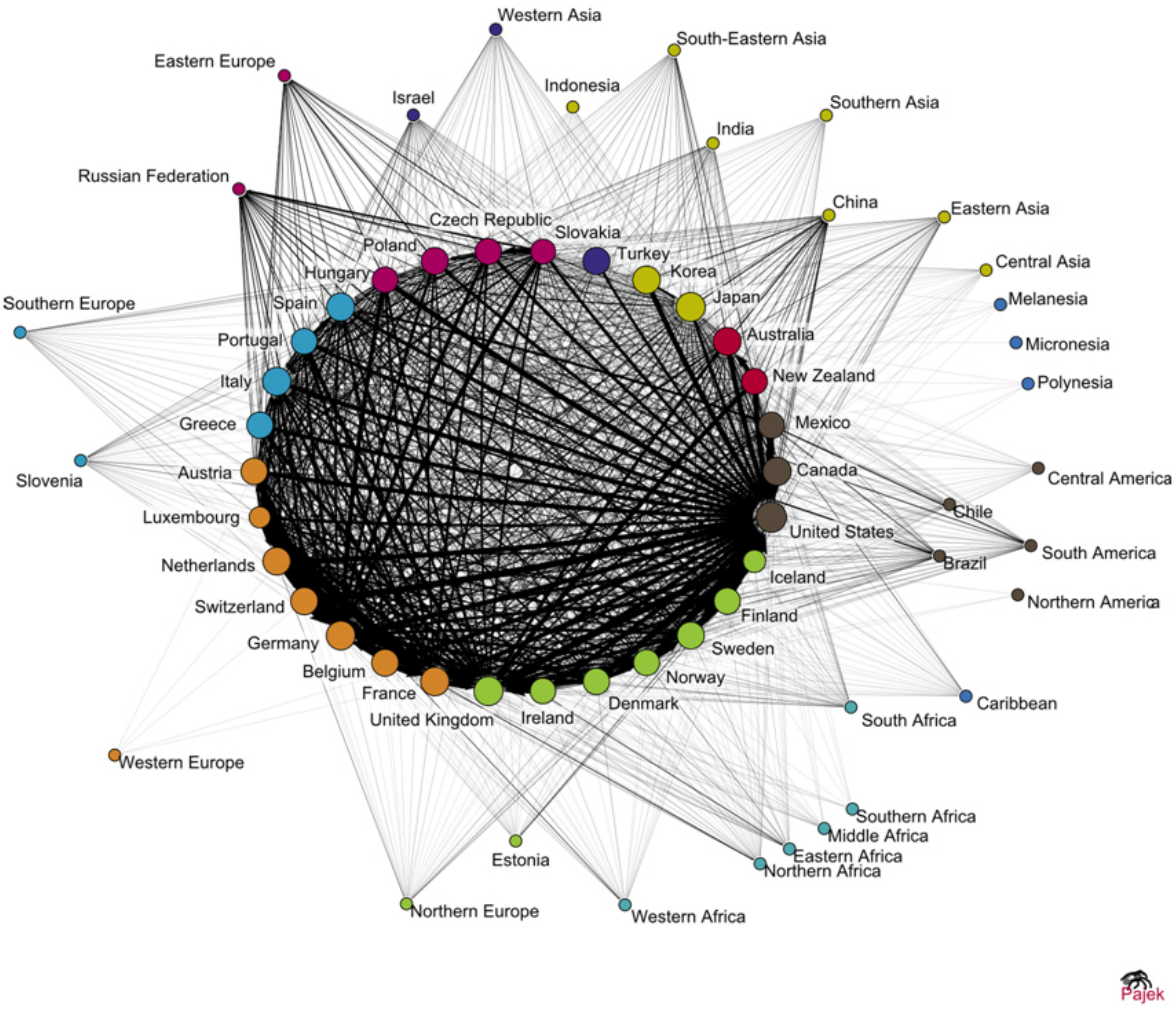


7.10 Country dot positions from top to bottom indicate the 'rank' assigned to each country, from rank one (only the United States) to rank six (Turkey through Korea, including New Zealand).

7.11 Each country collaborates with countries in its rank or higher. Belgium and Denmark are elevated to a higher rank than would otherwise be expected, specifically due to their close reciprocal ties with another highly ranked country: the Netherlands and Sweden respectively.

7.12 Inclusion of all collaborations from the OECD to countries from outside the OECD creates a more complex network chart. In Figure 15, ray line thickness is determined by the proportion of a nation's total publications that involve collaboration with the target country. Country dots are coloured by the region to which they belong, and for OECD countries, country dot diameter is indicative of the *log* number of publications by that country between 2002 and 2007.

Figure 15 Proportion of OECD country publications co-authored with other countries or regions

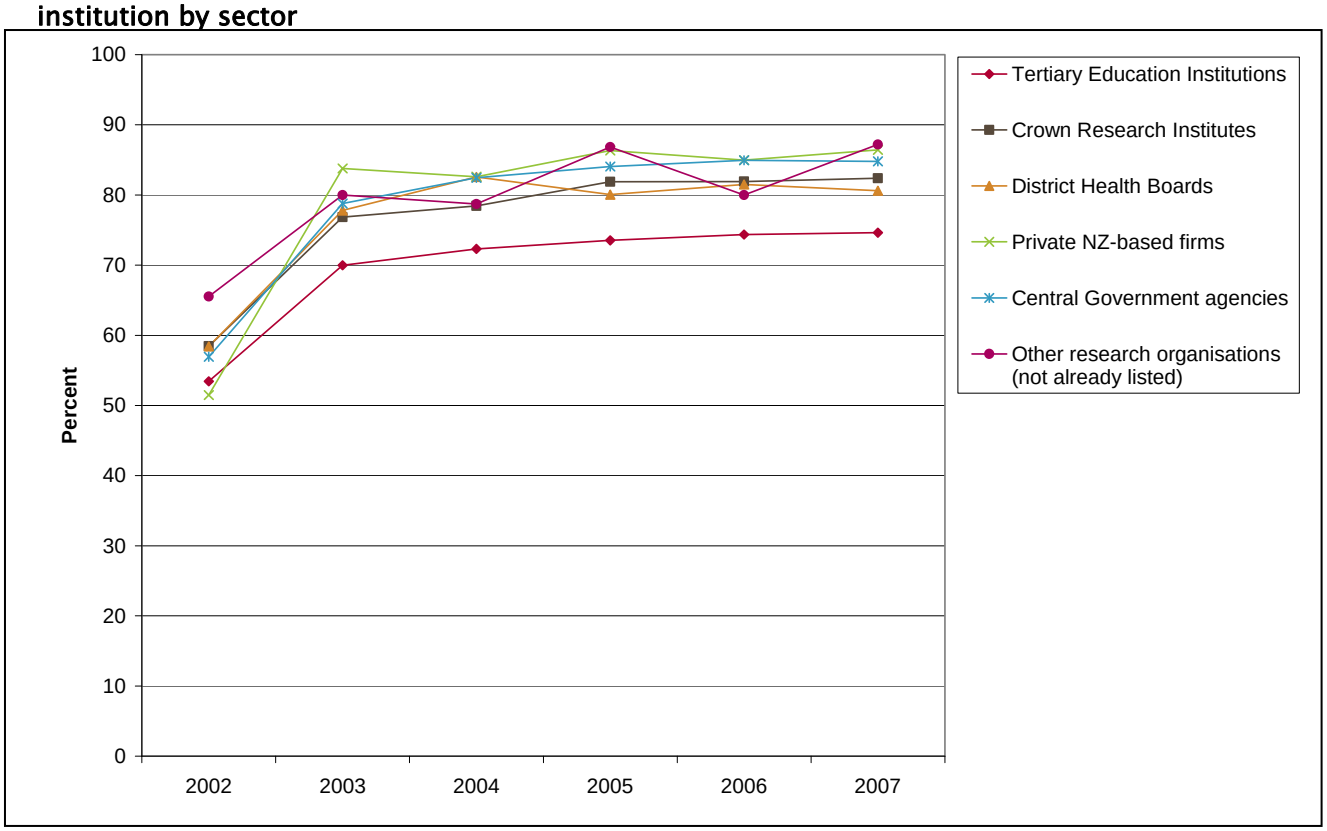


7.13 Within the dataset, OECD countries collaborate heavily with each other, but to a much smaller degree with other countries. Where there is evidence of substantial ongoing collaboration between an OECD country with a country outside the OECD, these links appear to be driven either by geographic proximity (e.g. Slovakia, Poland and Hungary have ties with Eastern Europe and Russia) or the ongoing legacy of historical ties (e.g. France and Northern Africa, or Portugal and Brazil).

COLLABORATIONS BY SECTOR

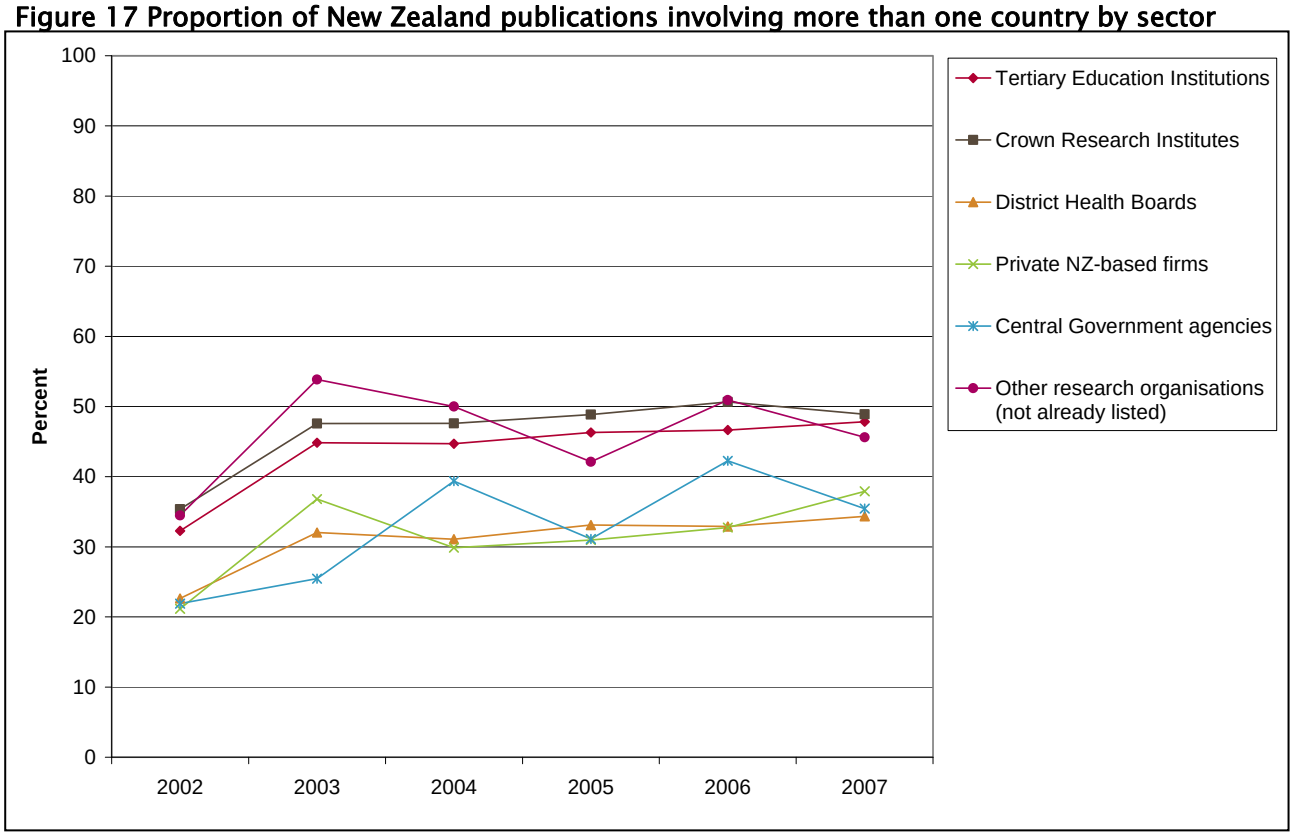
7.14 All major research sectors in New Zealand show increasing levels of multi-institutional collaboration over the period 2002-2007 (see Figure 16). The Tertiary Education sector showed the lowest level of multi-institutional collaboration by a sector. However, even this lowest level was reasonably high, as 71% of publications in the Tertiary Education sector over this period had authors from more than one institution.

Figure 16 Proportion of New Zealand publications involving authors from more than one institution by sector



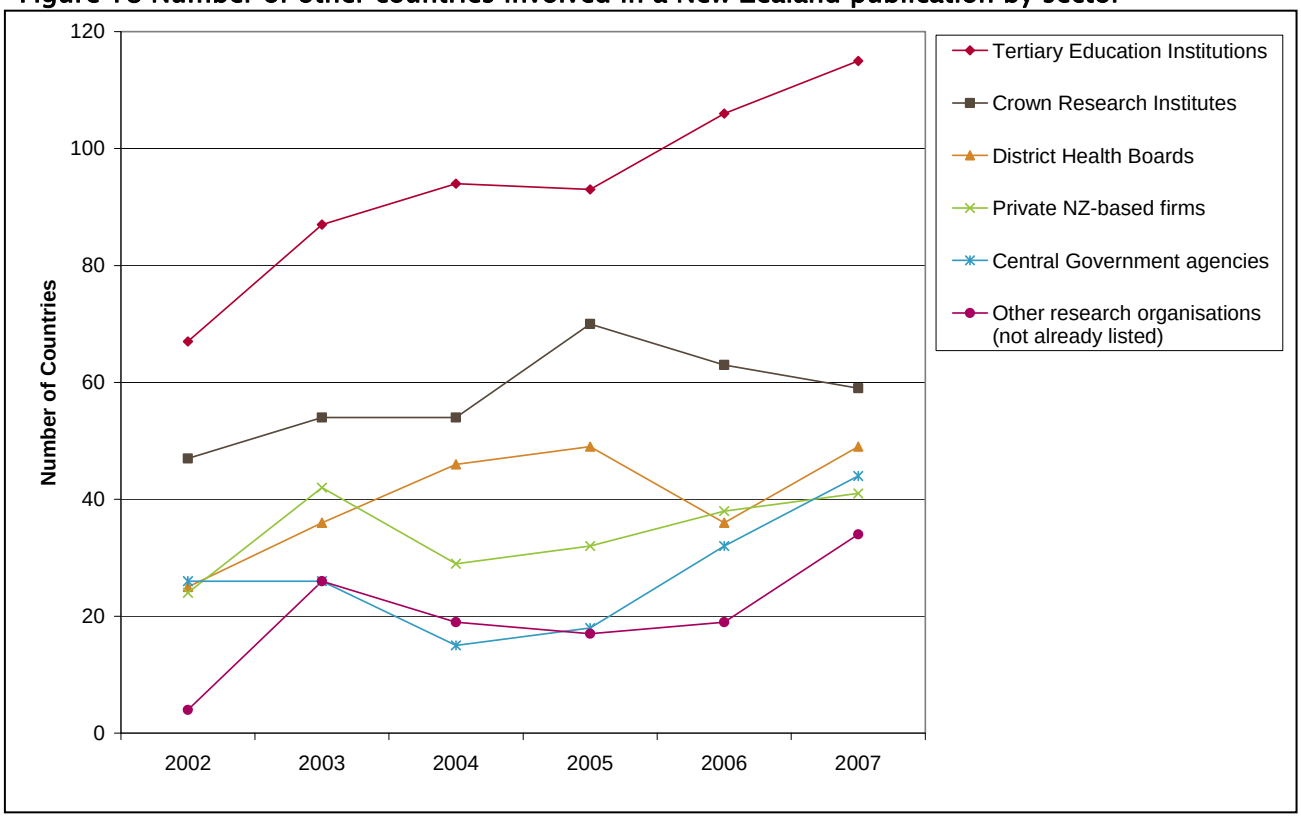
7.15 All major research sectors have shown increasing levels of international collaboration over the period 2002 to 2007 (see Figure 17). In terms of the likelihood of international collaboration, research sectors can be divided into two groups. For CRIs, Tertiary Education institutions, and other research organisations, almost half of all publications over the period 2002 to 2007 had international co-authors. For central government, DHBs, and private firms, roughly a third of all publications over this period had international co-authors.

Figure 17 Proportion of New Zealand publications involving more than one country by sector



7.16 Universities collaborate with the greatest number of countries. During 2002-2007, New Zealand universities published papers with co-authors from 151 different countries. Nevertheless, all sectors dealt with a range of countries (see Figure 18). The number of countries each sector collaborated with appears to increase over time, although this increase is strongest in the Tertiary Education sector.

Figure 18 Number of other countries involved in a New Zealand publication by sector

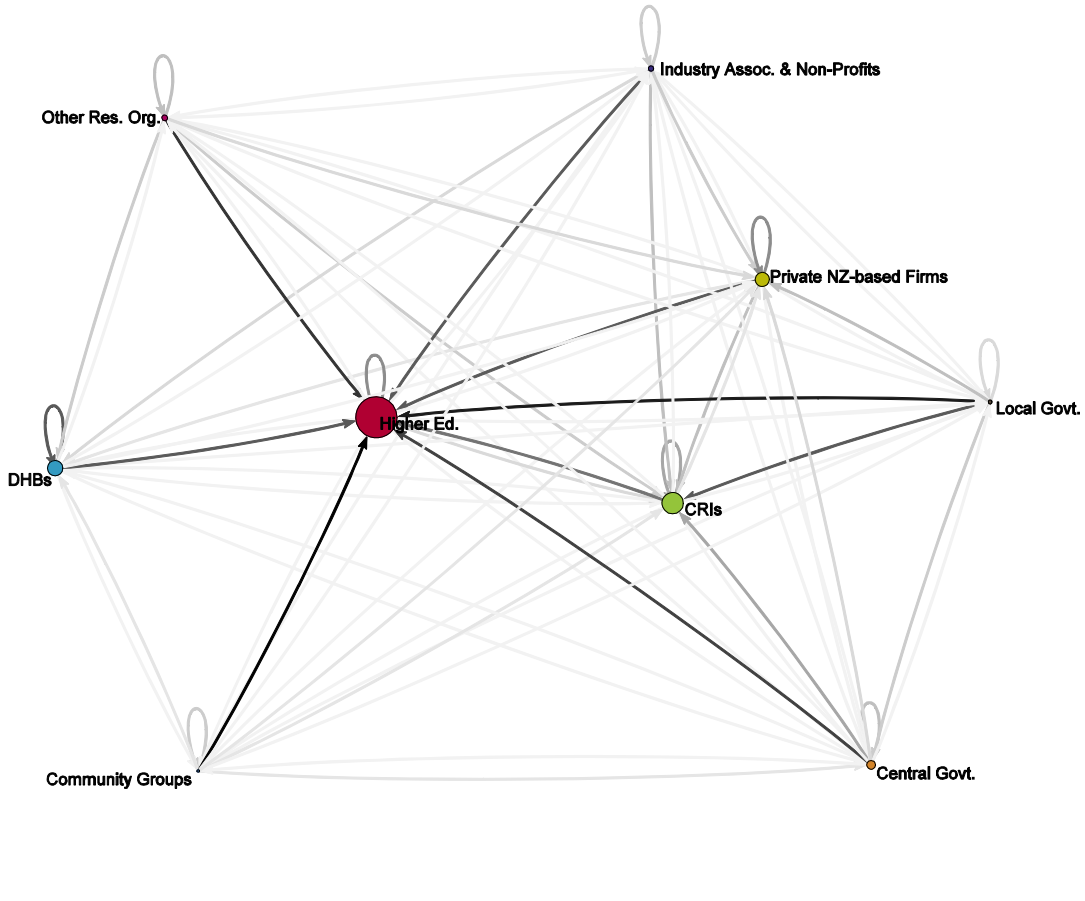


7.17 Figure 19 is a network chart of intra-New Zealand collaboration by sector-affiliation of author. The thickness of each ray line (as well as of each line that loops back on its origin) indicates the proportion of the sector's publications that are co-authored with the target sector.

7.18 The Tertiary Education sector is the most common partner for intra-New Zealand collaboration. The proportion of publications involving collaboration with the Tertiary Education sector exceeds the proportion of publications involving multi-author collaboration within each sector itself. Although for DHBs, this difference is small.

7.19 The proportion of intra-New Zealand collaboration is less than the proportion of international collaboration in nine out of ten sectors; with the exception again being DHBs. (The proportions of total publications demonstrating DHB to DHB collaboration, DHB to Tertiary Education collaboration, or DHB to international collaboration, are roughly equal.)

Figure 19 Inter-sector collaboration in New Zealand



8. Institutions

8.1 Previous chapters have examined the New Zealand research system as a whole. This chapter takes a more detailed view, looking at individual institutions and analysing their individual areas of strength and focus, and patterns of collaboration.

TERTIARY EDUCATION INSTITUTIONS

8.2 Between 2002 and 2007, Scopus recorded 28,745 publications with at least one author in a New Zealand Tertiary Education institution (see Table 2 on page 7). This represents 71% of total New Zealand publications.

8.3 All universities have increasing publication rates over 2002-2007. Over half of all New Zealand university publications during this period came from the University of Auckland or the University of Otago (see Table 9). There is a substantial difference between the University of Otago's publication rate, and Massey University's publication rate, which is the next largest.

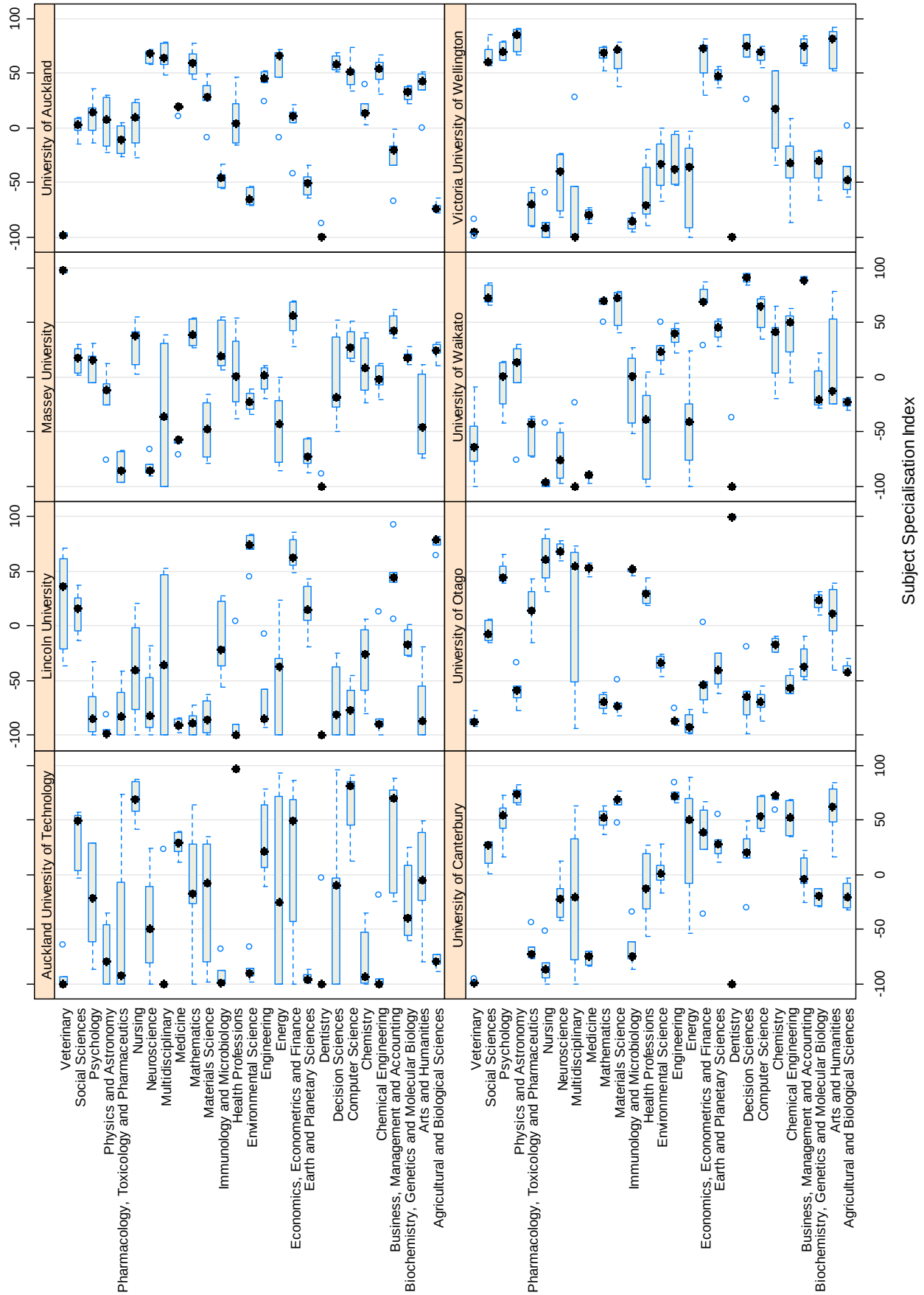
Table 9 Publications by Tertiary Education Institutions

	Year of publication						
Tertiary Education Institutions	2002	2003	2004	2005	2006	2007	Total
University of Auckland	1,025	1,237	1,368	1,556	1,760	1,863	8,809
University of Otago	912	1,125	1,132	1,377	1,389	1,448	7,383
Massey University	419	518	624	867	905	937	4,270
University of Canterbury	436	548	614	664	723	658	3,643
Victoria University of Wellington	236	263	406	431	509	495	2,340
University of Waikato	186	269	271	357	349	317	1,749
Lincoln University	99	130	174	173	162	182	920
Auckland University of Technology	48	87	134	184	226	203	882
UNITEC Institute of Technology	19	28	35	41	44	40	207
All other Tertiary Education Institutions	18	39	44	60	47	56	264
Total	3,258	4,001	4,528	5,382	5,763	5,813	28,745

Note – The sum of the parts may be greater than the total, because many publications have authors from more than one Tertiary Education Institution.

8.4 Given that the University of Auckland and the University of Otago have medical schools, and that medical journals are very well represented within the coverage of the Scopus database, and that medicine is a field of research where publication culture and tradition leads to a larger number of publication outputs than other disciplines, these universities' higher publication rates are not surprising.

Figure 20 Subject Specialisation Indexes for New Zealand's main universities



8.5 Figure 20 sets out box and whisker plots of the Subject Specialisation Indices (SSIs) for New Zealand's eight main universities during 2002-2007. For each subject area, the dark dot indicates the median SSI over this period; the margins of the box show the 25th percentile to the 75th percentile SSI; and the whiskers extend to the range boundary, but are limited to 1.5 times the interquartile range. Points shown beyond this range are outliers.

8.6 Perhaps unsurprisingly, Lincoln University and Auckland University of Technology (AUT) are specialised in the narrowest range of subjects. Lincoln has strong specialisation in agricultural and biological sciences; environmental science; veterinary; economics, econometrics and finance; business, management and accounting; and, to a lesser extent, social sciences and earth and planetary sciences. AUT focuses broadly on health services publications (health professions; nursing; and medicine), social and economic sciences (including business studies); and computer science.

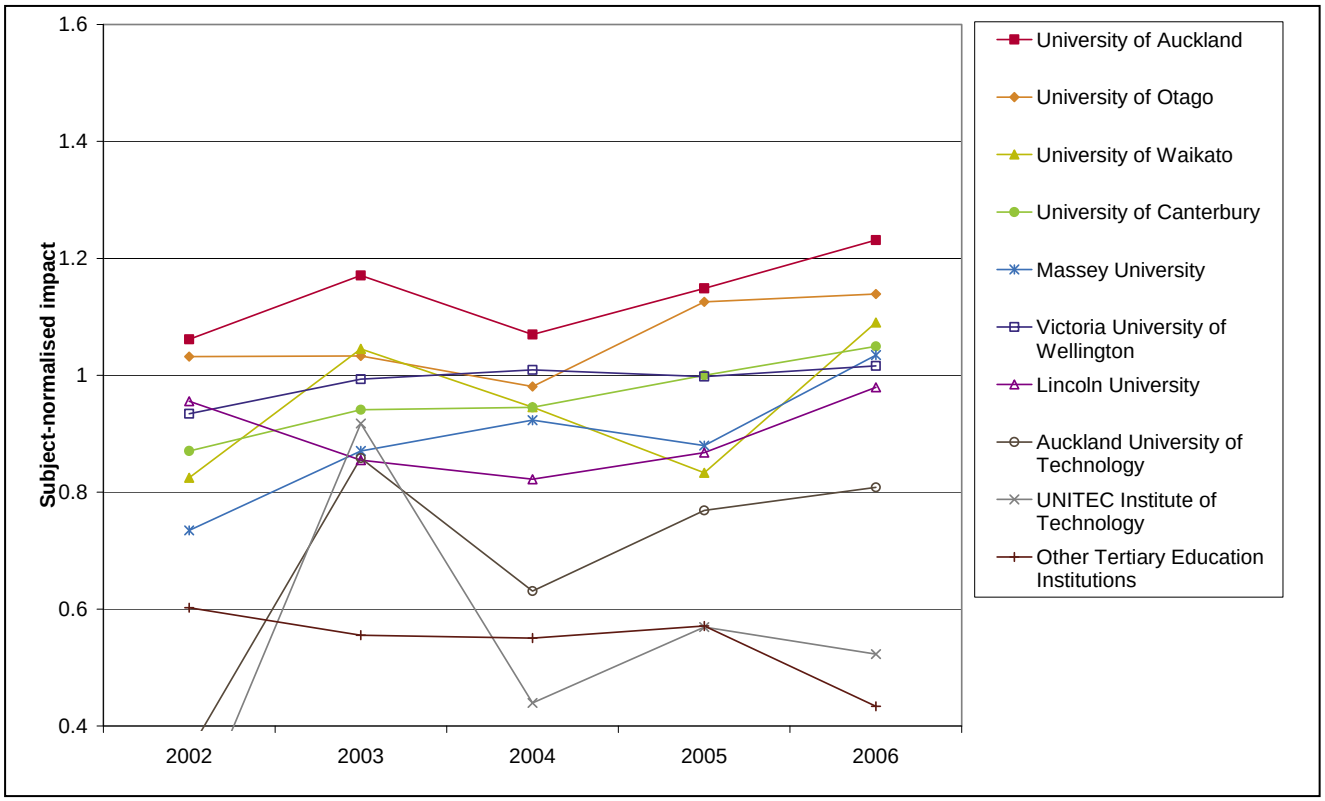
8.7 The University of Otago shows strong specialisation in the medical sciences (nursing; neuroscience; medicine; immunology and microbiology; dentistry; and to a lesser extent, psychology; pharmacology, toxicology and pharmaceuticals; health professions; and biochemistry, genetics and microbiology). Otago also shows a degree of specialisation in the arts and humanities.

8.8 The University of Auckland also shows specialisation in medical science, but apparently has a stronger focus in the physical sciences (engineering; energy; materials science; chemistry; chemical engineering); mathematics; decisions science; and computer science. It also shows a strong degree of specialisation in the arts and humanities.

8.9 Victoria University of Wellington and the University of Canterbury show a lot of similarities in their areas of specialisation (psychology; physics and astronomy; mathematics; materials science; chemical engineering; computer science; arts and humanities). Their most significant difference is the University of Canterbury's focus on engineering. Massey University's strongest areas of specialisation are veterinary; economics, econometrics and finance; and business, management and accounting. Waikato University primarily specialises in business, management and accounting; social sciences; mathematics; materials science; and decision science.

8.10 Figure 21 shows citation impact by university over the period 2002-2006. Some universities show evidence suggestive of increasing citation impact. For other universities there is less clear evidence of either increasing or decreasing citation impact.

Figure 21 Subject-normalised citation impact of publications for Tertiary Education Institutions, 2002-2006

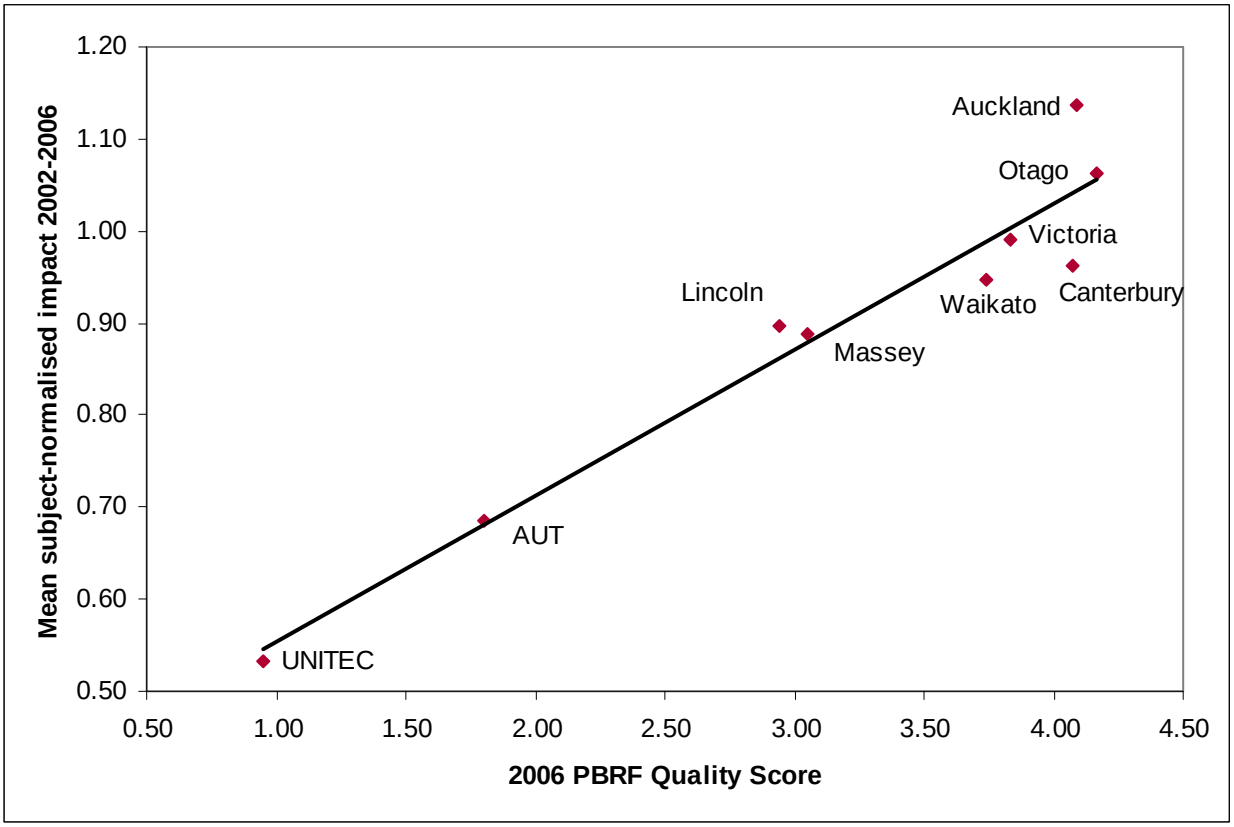


8.11 Citation impact results for universities (and for CRIs – see Figure 24) also seem to show evidence of regression to the mean, i.e. impact results for larger institutions (those with more publications per year) tend towards the mean subject-normalised impact = 1.

8.12 While all major Tertiary Education institutions increased their impact 2002-2006, the level and stability of this increase varied. UNITEC's publishing impact data should be treated with some caution, as it is based on only 158 publications.

8.13 Since mean subject-normalised citation rate is a scale-free indicator reflecting the aggregate international impact of an institution, it is possible to compare it to PBRF Quality Scores which have a similar intent. Comparison by institution, where both a Quality Score assigned in the 2006 PBRF assessment, and a sufficiently robust number of publications for 2002-2006 is available, shows a high degree of correspondence (see Figure 22).

Figure 22 Comparison of mean subject-normalised citations and PBRF Quality Score



8.14 Researcher publications of the major Tertiary Education institutions appear to have an average subject-normalised citation impact very similar to what could be anticipated from the PBRF's Quality Score determination. The biggest observable differences are that, based on the bibliometric dataset used, the University of Auckland has a somewhat higher publishing impact than it's PBRF Quality Score would suggest, and the University of Canterbury has a somewhat lower publishing impact than it's PBRF Quality Score would suggest.

CROWN RESEARCH INSTITUTES

8.15 Between 2002 and 2007, Scopus recorded 7,281 publications with at least one author affiliated to a Crown research institute (see Table 2 on page 7). This represents 18% of total New Zealand publications.

8.16 The National Institute of Water & Atmospheric Research (NIWA), AgResearch and Landcare Research produced the greatest number of publications during the period 2002–2007.

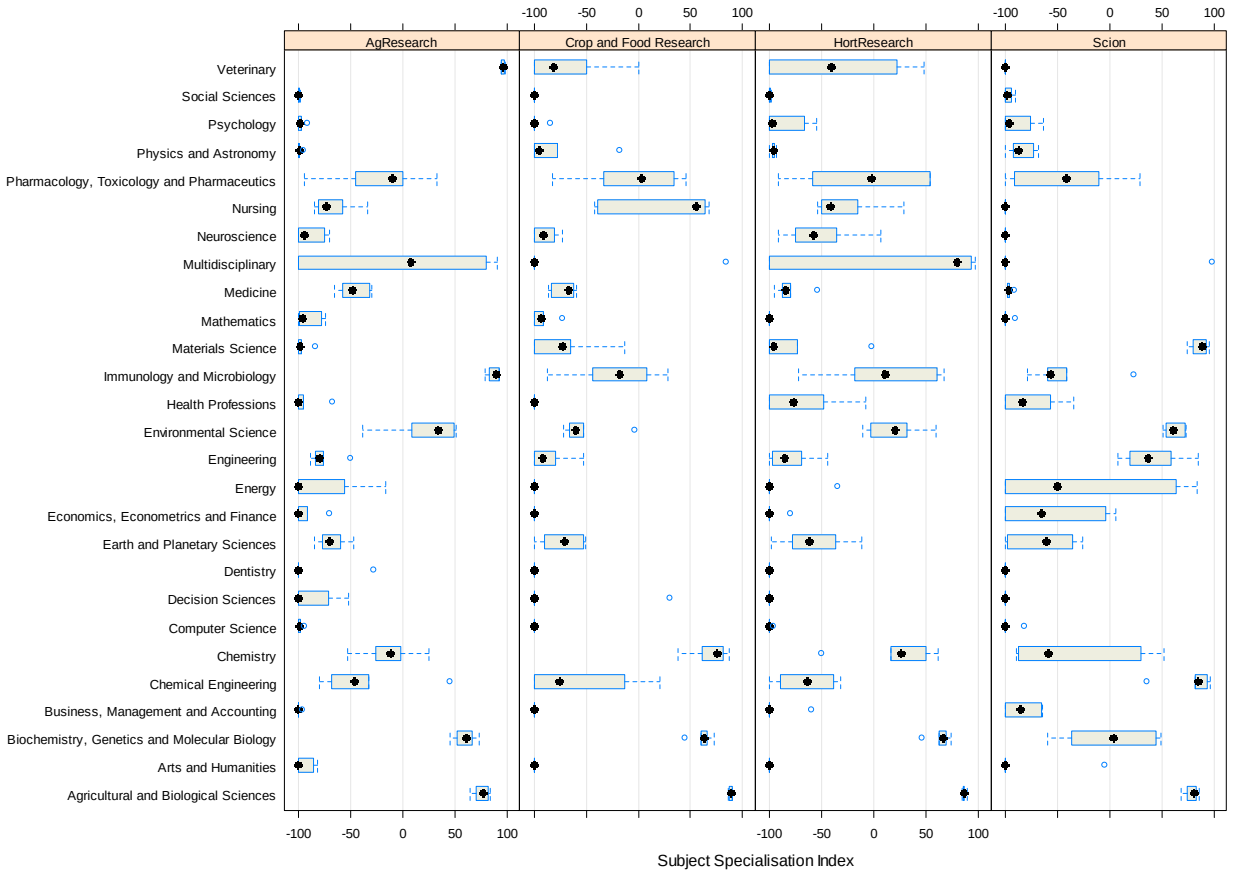
Table 10 Publications by Crown Research Institute

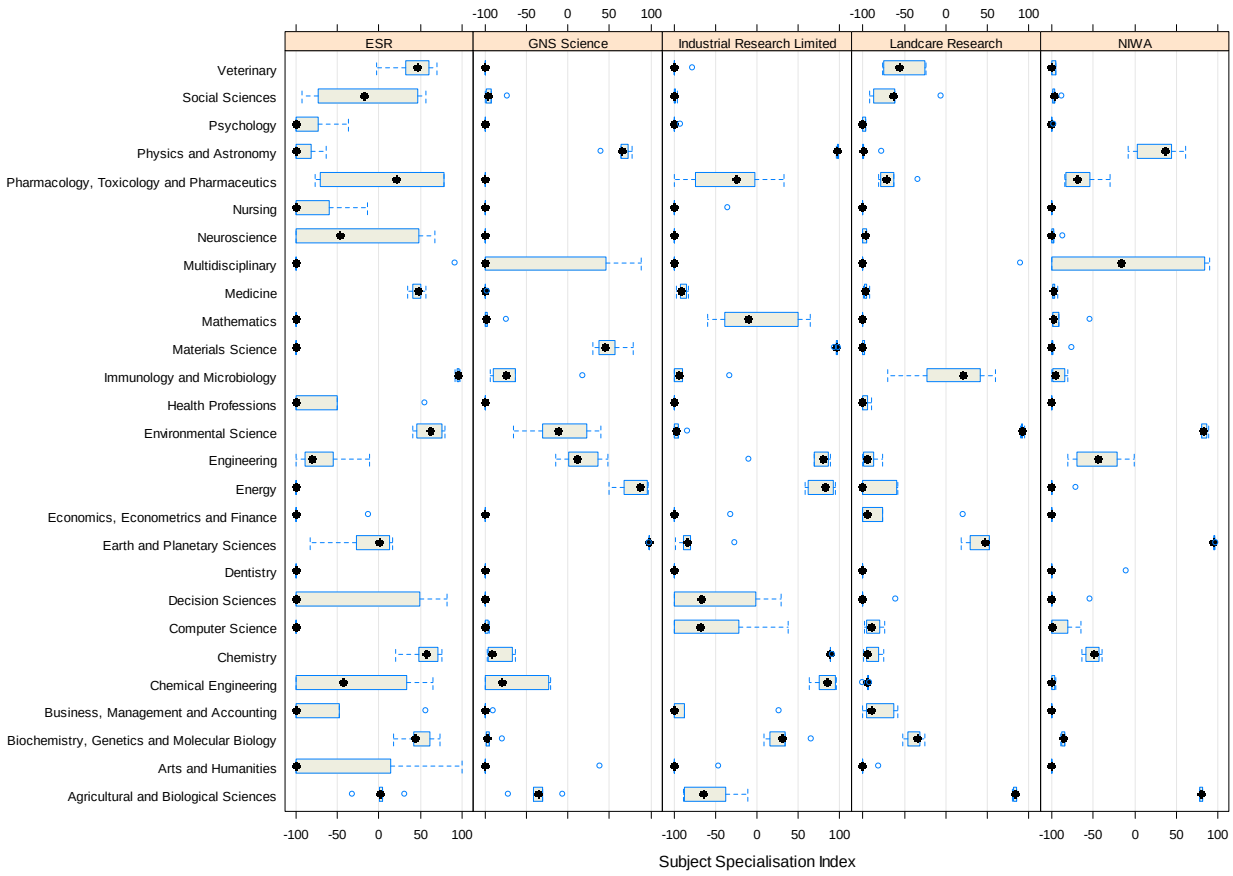
	Year of publication						
Institution	2002	2003	2004	2005	2006	2007	Total
National Institute of Water & Atmospheric Research	227	248	228	277	270	253	1,503
AgResearch	208	216	220	237	266	263	1,410
Manaaki Whenua – Landcare Research	182	210	215	218	218	207	1,250
GNS Science	102	130	146	136	152	142	808
HortResearch	87	112	105	127	161	150	742
Industrial Research Limited	93	116	122	103	114	125	673
New Zealand Institute of Crop and Food Research	92	85	83	108	85	68	521
Scion	70	86	113	72	53	36	430
Institute of Environmental Science & Research	35	55	48	60	67	86	351
Total	1,061	1,192	1,212	1,259	1,295	1,262	7,281

Note – The sum of the parts may be greater than the total, because many publications have authors from more than one CRI.

8.17 Figure 23 sets out Subject Specialisation Indexes (SSIs) for New Zealand's Crown research institutes. For each subject area, the dark dot indicates the median SSI over this period; the margins of the box show the 25th percentile to the 75th percentile SSI; and the whiskers extend to the range boundary, but are limited to 1.5 times the interquartile range. Points shown beyond this range are outliers.

Figure 23 Subject Specialisation Indexes for New Zealand's Crown research institutes





8.18 As we might expect from their unique role in the science system, CRIs display a much higher level of specialisation and focus than universities. Most CRIs show a small number of specialised subjects (e.g. no more than six) on which they are narrowly focussed (e.g. these subjects are usually closely related, such as chemistry and chemical engineering). CRIs also tend to show a large number of subjects in which they do not publish at all.

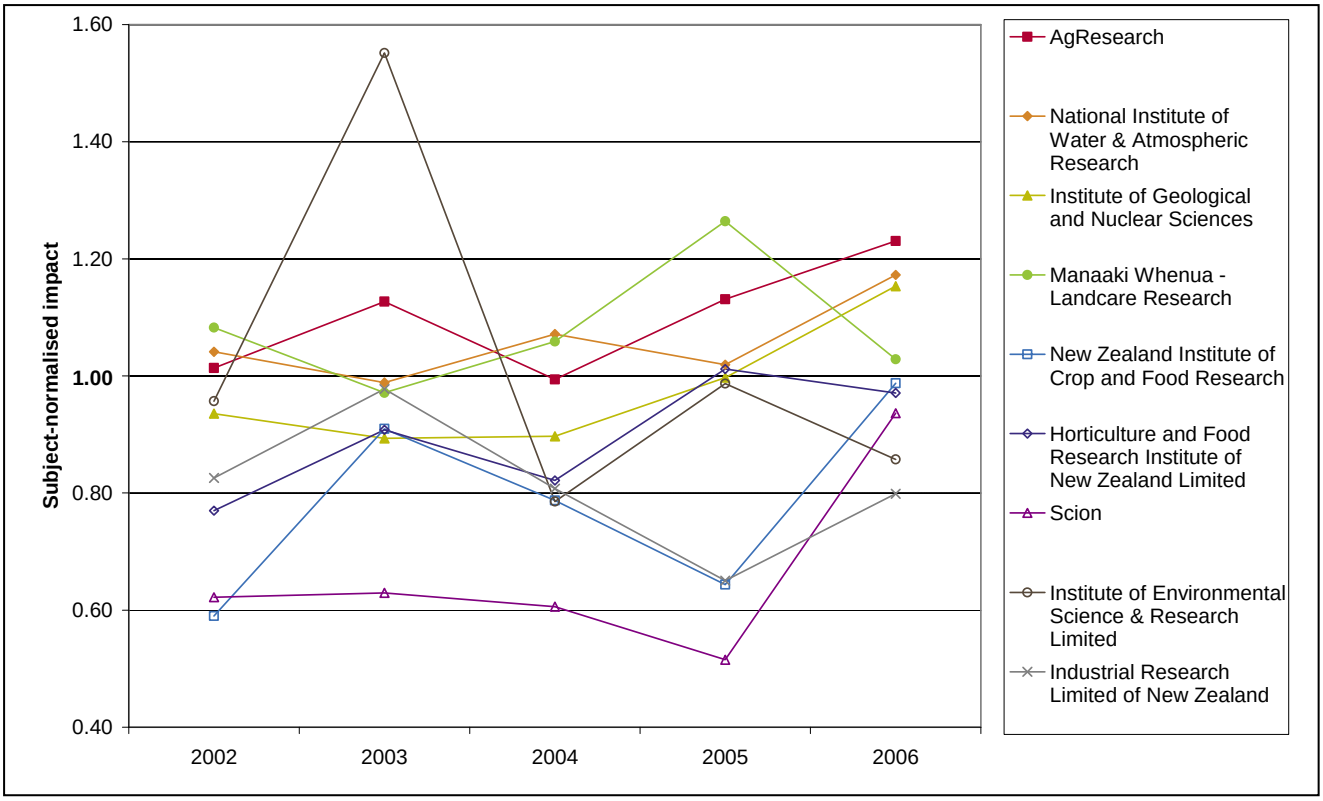
8.19 The three CRIs that published the most during the period 2002-2006 (NIWA, AgResearch, and Landcare Research) also published research having the highest impact amongst CRIs. They were the only CRIs that maintained a subject-normalised impact above the OECD average for at least four of the five years 2002-2006 (see Table 11).

Table 11 Subject-normalised impact for publications from CRIs, relative to OECD average

	Year of Publication					
Institution	2002	2003	2004	2005	2006	Mean
AgResearch	1.01	1.13	0.99	1.13	1.23	1.10
Manaaki Whenua - Landcare Research	1.08	0.97	1.06	1.26	1.03	1.08
National Institute of Water & Atmospheric Research	1.04	0.99	1.07	1.02	1.17	1.06
Institute of Environmental Science & Research	0.96	1.55	0.79	0.99	0.86	1.03
GNS Sciences	0.94	0.89	0.90	1.00	1.15	0.98
HortResearch	0.77	0.91	0.82	1.01	0.97	0.90
Industrial Research Limited of New Zealand	0.83	0.98	0.81	0.65	0.80	0.81
New Zealand Institute of Crop and Food Research	0.59	0.91	0.79	0.64	0.99	0.78
Scion	0.62	0.63	0.61	0.52	0.94	0.66

8.20 Figure 24 shows citation impact by CRI over the period 2002–2006. Some CRIs show evidence suggestive of increasing citation impact. For other CRIs there is less clear evidence of either increasing or decreasing citation impact.

Figure 24 Subject-normalised citation impact of CRI publications by CRI by year 2002–2006

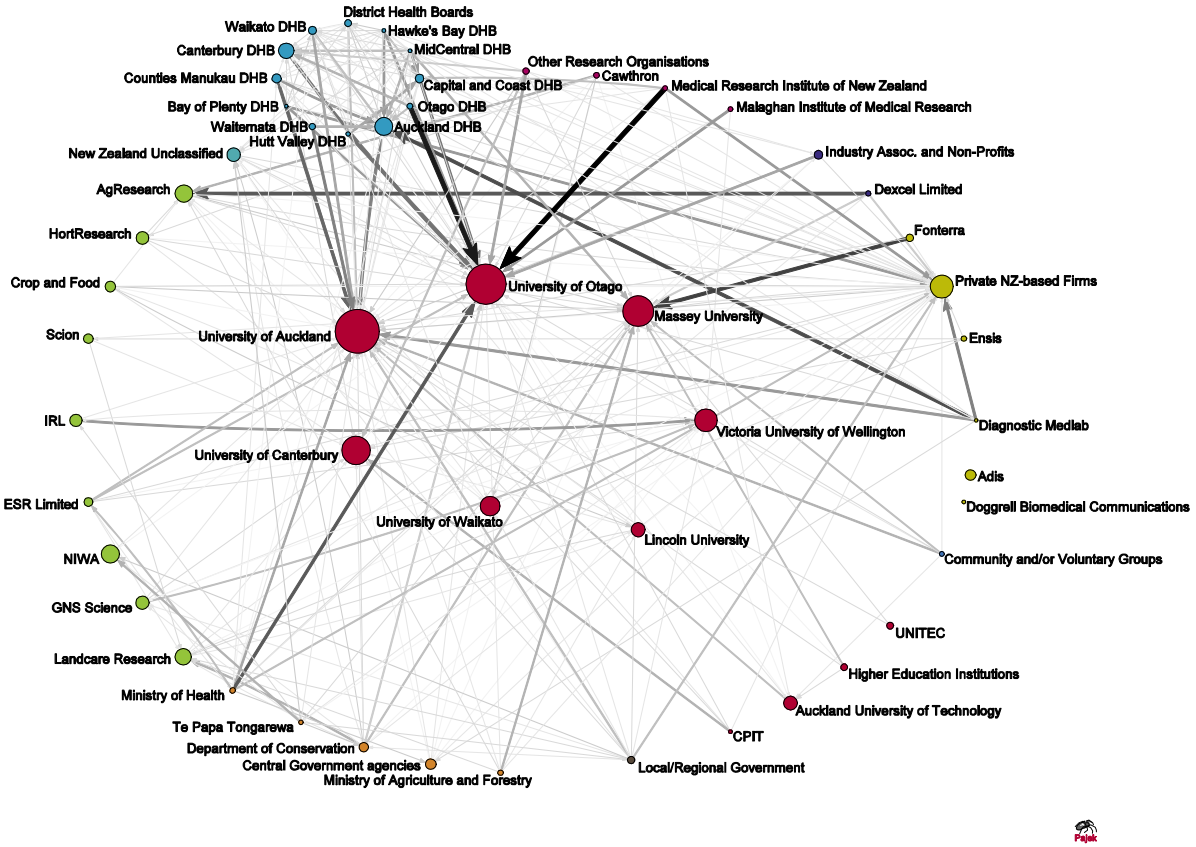


8.21 The citation impact results for CRIs (and for universities – see Figure 21) also seem to show evidence of regression to the mean, i.e. impact results for larger institutions (those with more publications per year) tend towards the mean subject-normalised impact = 1.

COLLABORATIONS BY INSTITUTION

8.22 For New Zealand publications 2002-2007, 70% involved authors from more than one institution. Figure 25 is a network chart of the domestic collaborations between New Zealand's research institutions.

Figure 25 Network chart of publication collaborations between New Zealand institutions



8.23 The ray lines in this figure represent publication collaboration where the proportion of publications involving the target institution exceeds a threshold of 4% of that institution's total publications. The thickness and darkness of each ray line indicates the increasing size of the proportion of publications represented. For example, for 2002-2007, 45% of all Otago DHB publications involved a collaboration with the University of Otago, while only 4% of Auckland University of Technology publications involved such a collaboration. Institution dots are coloured using sector groupings, and each institution's dot diameter is determined by the total number of publications that were authored by that institution.

8.24 At the 4% threshold, the universities, especially Otago and Auckland, are the primary targets for publication collaboration.

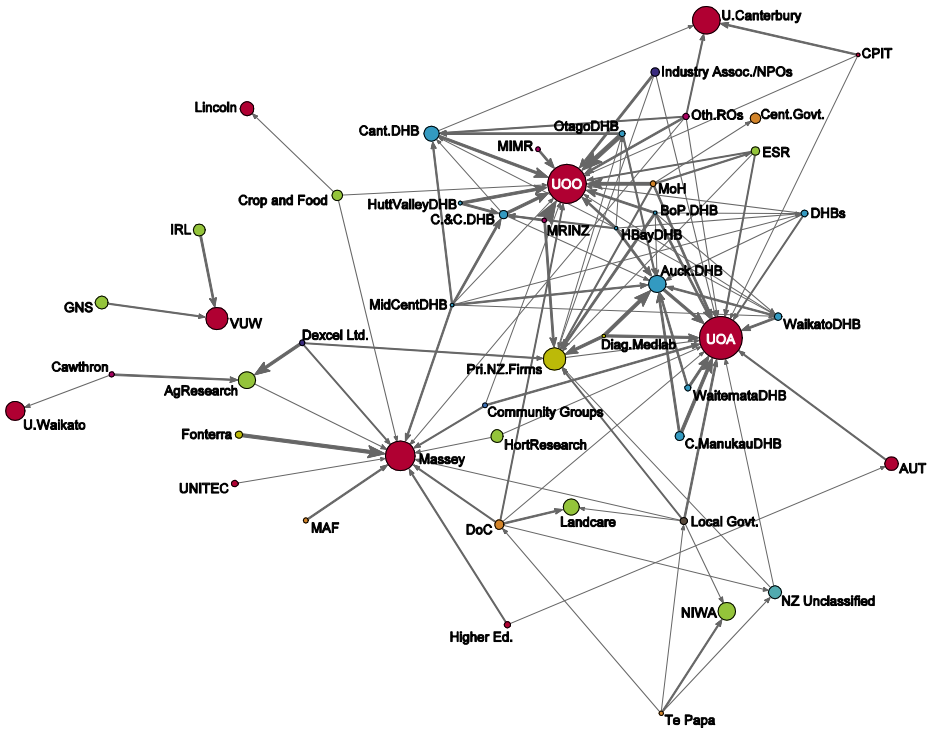
8.25 Some specific publication collaboration relationships worth noting include:

- Otago DHB, the Medical Research Institute of New Zealand, and the Ministry of Health, with the University of Otago.
- Fonterra with Massey.
- Dexcel with AgResearch.
- Diagnostic Medlab with Auckland DHB.

8.26 The existence and strength of publication collaboration appears well explained by a combination of corresponding institutional specialities (e.g. Fonterra with Massey), and geographic proximity (e.g. each region's DHB with that same region's university).

8.27 Figure 26 is another network chart of these institutional publication collaboration relationships. However, it only shows linkages where the proportion of publications involving the target institution exceeds a threshold of 8% of that institution's total publications.

Figure 26 Network chart of *major* collaborative relationships between New Zealand institutions



9. Conclusion

9.1 The purpose of this report is to identify areas of focus and strength within New Zealand's research community, show patterns of linkage and collaboration, and compare New Zealand's science performance with the rest of the OECD. We have accomplished this purpose, although within the theoretical and known practical limitations and constraints of bibliometric analysis, and the bibliometric dataset used.

9.2 During 2002-2007, both the rate and impact of New Zealand publications have increased at a significantly higher rate than has been recorded in any other New Zealand national bibliometric reports published between 1986 and 2004. While all sectors have increased their rate of publication, the growth in output was primarily driven by the Tertiary Education sector, which produced 78% more publications in 2007 than in 2002.

9.3 There is no evidence that this increase in publication rate has been associated with a decline in quality. Indeed, in 2006, publications from New Zealand's six largest universities had a subject-normalised citation impact greater than the OECD average. This report therefore supports the findings of the Ministry of Education, that the introduction of the Performance-Based Research Fund (PBRF) has been associated with a significant increase in both the number and impact of publications from universities.[5]

9.4 Compared to the OECD, research publication in New Zealand is more prolific in the biological and environmental sciences, but less prolific in the physical and chemical sciences, and engineering. While the overall impact of research publication in New Zealand is average compared to the OECD, in some specific disciplines New Zealand publications have an impact well above the OECD average.

9.5 New Zealand researchers collaborate frequently with other authors, institutions and countries. Internationally, this is primarily but not solely with the United States, Australia and the United Kingdom. The number of countries collaborated with has significantly increased during 2002-2007.

9.6 New Zealand researchers publish at roughly the same rate per researcher employed as in countries like Australia, Ireland, Denmark, Norway and Sweden, and at a higher rate than Finland. However, New Zealand's publication output per dollar of Gross Expenditure on Research and Development (GERD) is significantly greater than these countries. New Zealand scientific publication is therefore relatively cost effective, and more similar in cost to that of the Slovak Republic, Poland and Greece, than to the countries we traditionally compare our science system to, and aspire to have a science system like (i.e. the Nordic countries, Australia and Ireland).

[5] *Ministry of Education (2009) Making an Impact p.6*