MINISTRY OF EDUCATION
Te Tāhuhu o te Mātauranga

(ex)Citing research

A bibliometric analysis of New Zealand university research 1981-2005

Research and knowledge creation

This report forms part of a series called Research and knowledge creation.

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Acknowledgements:
The authors gratefully acknowledge comments provided by Roger Smyth (Ministry of Education), Jonathan Boston (Victoria University of Wellington) and four reviewers from the Tertiary Education Commission on earlier drafts of this report. The authors also gratefully acknowledge Alison Lipski who proof-read this report.

All views expressed in this report, and any remaining errors or omissions, remain the responsibility of the authors.

Published by:
Tertiary Sector Performance Analysis and Reporting
Strategy and System Performance
Ministry of Education

This report is available from the Ministry of Education's Education Counts website:
http://www.educationcounts.edcentre.govt.nz

July 2007

ISBN (Web) 978-0-478-13689-0
ISBN (Print) 978-0-478-13688-3

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1 Summary

This report uses a newly unified bibliometric database from Thomson Scientific to analyse the impact of research, across various subject disciplines, by New Zealand universities between 1981 and 2005. It represents an advance on previous studies, in terms of both the length and breadth of the analysis, and adds to existing measures of research volume and quality. Importantly, it provides benchmark data that will assist in evaluating the impact of the Performance-Based Research Fund (PBRF) over time.

Bibliometric measures of research, especially those dealing with citations, are increasingly being used worldwide to assess the performance of research institutions. In this report, the key measure used to analyse the academic impact of research is the average number of citations per paper. As publications that are of a higher quality and impact generally attract a higher number of citations, a higher average number of citations per paper should reflect higher quality research. However, due to the problems of differing rates of citation among disciplines, and the fact that citation rates are naturally rising over time with the increased volume of research, a relative measure of research impact is used in this report. This calculates the ratio of average citations per paper in the New Zealand universities to the average number of citations for the world, in assigned subject areas.

The usefulness of bibliometric analysis varies between subject disciplines, reflecting differences in publishing conventions in different fields. Analysis in the physical and medical sciences is more robust than in disciplines such as the social sciences and humanities. Because of this and other important caveats, the results presented in this report should be treated carefully.

To align the results of this report with other measures of research performance and therefore increase the relevance of the analysis, the 106 subject areas in the Thomson Scientific dataset were aggregated into 10 of the 12 broad areas used in the PBRF to group disciplines – the PBRF subject panels. The PBRF subject panels omitted from this analysis were 'Māori knowledge and development' and 'creative and performing arts'. The 'Māori knowledge and development' panel was omitted as it is impossible from the Thomson Scientific subject categories to assign publications to this panel. The 'creative and performing arts' panel was omitted as there were few publications in this subject area in the Thomson Scientific database.

The analysis showed that the relative impact of university research varies considerably, both among and within panels over time. At the sector level, university research in the 'health' panel area achieved the highest research impact during the period between 1981 and 2005. This was followed by research in the 'medicine and public health' panel. Several panels exhibited quite large variation in research impact over time, with panels with smaller numbers of publications, such as 'business and economics', being especially prone to significant variation.

The key results of the analysis of individual university performance in each of the 10 subject panels were:

- *Engineering, technology and architecture*: the two universities with well established engineering schools, Auckland and Canterbury, exhibited similar research impact over time with relative impact peaking in the early 1980s at around the world average. In recent time periods, the research impact has generally increased at both universities towards the world average.

- *Mathematical and information sciences and technology*: all of the main producers of research publications in this panel have experienced an upwards trend in their relative research impact over time. In the most recent time period (2001-2005), four of the eight universities exhibited a relative impact score above the world average.

- *Physical sciences*: the performance of the universities in this panel was relatively strong and has exhibited the most stability of the panels over time. Several universities exhibited a relative impact that was above the world average at some stage over the last 25 years. In the most recent time period, four of the universities exhibited a relative impact either above or close to the world average.

- *Biological sciences*: although most universities in this panel have exhibited a relative impact score below the world average over the 25-year period of analysis, since 1999-2003 most universities have shown an increase in relative impact. The 'biological sciences' is an area where the United States and Europe devote considerable effort and hence a relative impact score of less than one should be regarded in that context.

- *Medicine and public health*: the universities with medical schools, Auckland and Otago, dominate this panel in terms of publications. Over the 25 year period of this analysis the University of Auckland achieved a relative impact score up to 1.6 times the world average at times, while the University of Otago achieved a score around the world average. In recent years the gap in performance between the two universities has narrowed substantially.

- *Health*: the two largest producers of publications in this area, Massey University and the University of Otago, both exhibited strong performance with a relative impact ratio well above the world average for extended periods between 1981 and 2005.

- *Business and economics*: the performance of the universities in this panel was mixed, with the University of Auckland achieving the highest relative impact score in the most recent five-year period (2001-2005). This panel also exhibited substantial variation in performance, which is partly due to the small number of publications in this area, which inflates the impact of a small number of highly cited papers.

- *Education*: this panel also exhibited a high degree of variation, with most universities exhibiting the highest relative impact at various times. However, in the most recent five-year period (2001-2005), research at the University of Auckland achieved the highest relative impact score.

- *Social sciences and other cultural/social studies*: in this panel, the performance of the University of Otago was significantly above that of other universities, with a relative impact score that approached two times the world average at stages. However, this strong relative performance was in part a result of the large number of publications in the psychology subject area at Otago.

- *Humanities and law*: the performance of universities in this area has been subject to a large amount of variation, a result of the low number of publications in the Thomson Scientific database. As a result, several universities have attained the highest relative research impact at various times over the last 25 years.

It is apparent from these results that no single university dominated at all times and across all panels. This variation in research impact is not unexpected, given the specialised nature of the research focus of the universities and the natural turnover in research staff at universities over time.

An aggregation of the narrow subject areas into PBRF panels can mask the performance of universities in specialist research areas. An analysis of research impact at the narrow subject level for the period 2001-2005 showed that in several narrow subject areas the research by New Zealand universities had an impact above the world average. At the university sector level, the top three

narrow subject areas were 'geological/petroleum/mining engineering', 'language and linguistics' and 'optics and acoustics'.

The top three narrow subject areas at each of the universities with relative impact scores above one were:[1]

- *Lincoln University*: 'agriculture/agronomy', 'animal sciences' and 'environment/ecology'
- *Massey University*: 'food science/nutrition', 'experimental biology' and 'biology'
- *The University of Auckland*: 'optics and acoustics', 'rheumatology' and 'mechanical engineering'
- *The University of Canterbury*: 'chemical engineering', 'engineering management/general' and 'environment/ecology'
- *The University of Otago*: 'paediatrics', 'inorganic and nuclear chemistry' and 'orthopaedics, rehabilitation and sports medicine'
- *The University of Waikato*: 'inorganic and nuclear chemistry', 'earth sciences' and 'aquatic sciences'
- *Victoria University of Wellington*: 'library and information sciences', 'environment/ecology' and 'mathematics'.

The fact that several universities and subject areas exhibited a relative research impact below the world average needs to be placed in context and is not necessarily an indicator of low research quality. A similar study of United Kingdom institutions found that only around a quarter of institutions in each subject area were above the world average. It also needs to be remembered that the bibliometric database used in this analysis does not capture all university research, especially that in the social sciences and humanities. This is particularly the case in a country like New Zealand, where publications are more likely to appear in journals that have a local bias and hence are less likely to appear in the Thomson Scientific database. In addition, the research performance of an institution needs to be considered across a variety of measures so that a balanced assessment of performance can be made. The results in this analysis provide just one part of this assessment.

Although the period of analysis used in this report is not able to capture any impact of the PBRF, the ability to update the bibliometrics database on an annual basis provides the opportunity for ongoing monitoring of the impact of the PBRF on research performance. This is especially the case in those subject disciplines where the Thomson Scientific database has good coverage of the research output produced, such as the sciences and medical sciences.

1 Auckland University of Technology only had one narrow subject area with a sufficient number of publications to be included in this analysis – this was in the area of 'orthopaedics, rehabilitation and sports medicine', which achieved a relative impact score of 0.9.

2 Introduction

The measurement of the research performance of New Zealand's tertiary education organisations (TEOs) is of considerable importance, given the vital role that TEOs play in the creation and transfer of knowledge which is a vital ingredient in the economic transformation of New Zealand. This applies to universities in particular, where the vast majority of research is undertaken in the tertiary education sector.[2]

In the past, the monitoring of the research performance of universities has mainly taken the form of counts of research outputs and the amount of external research income earned (for example, see Ministry of Education, 2004). The introduction of the Performance-Based Research Fund (PBRF) in 2004 has added another element to performance monitoring, that of the quality of research produced by New Zealand's TEOs.

This new study adds to the stable of existing performance measures by utilising a newly unified[3] bibliometric database to measure the research performance of universities – in the form of research impact - over an extended period of 25 years. Specifically, this study examines the academic impact of research (measured by citations per paper) by the New Zealand universities, both as a whole and individually, across several subject areas between 1981 and 2005.

Although the use of bibliometric data to measure the research performance of New Zealand universities is not new, the scale of the analysis and the length of the time period analysed represent an advance on previous studies. As a result, this analysis provides new insights into the research performance of New Zealand universities over the last 25 years. Importantly, the results of this analysis will also provide benchmark data for evaluating the impact of the PBRF over time.

This report has the following structure. The measurement of research impact through the use of citations is explored in section 3. This involves a detailed discussion on the advantages and disadvantages of bibliometric measures. In section 4, the dataset used and the method of measuring research impact in this study are presented. Section 5 then analyses the relative impact of New Zealand university research over the period 1981-2005. This involves firstly examining aggregated university performance across 10 PBRF subject panels. Then, the performance of individual universities in each of the 10 panels is examined. Section 6 presents the relative impact of university research in narrow subject areas. To end the report, a number of final conclusions are presented.

2 Ministry of Research, Science and Technology (2004).

3 This is where publications by authors in the Thomson Scientific database have been assigned to each tertiary education institution in New Zealand.

3 The use of citations to measure research performance

Bibliometric measures are increasingly being used to measure the research performance of tertiary institutions worldwide, with New Zealand being no exception. For example, Dale and Goldfinch (2005) analysed the performance of politics departments in Australasian universities, using citations data from the Web of Science.[4] Macri and Sinha (2006) used bibliometric information from the EconLit database to rank the performance of academics in Australasian university economics departments.

At the national, sector and institutional level, the Ministry of Research, Science and Technology has released a series of reports that use citations data from Thomson Scientific to analyse the research performance of New Zealand research institutions.[5] The latest report in this series used data from Thomson Scientific to analyse the citation of the research by New Zealand universities across a variety of academic disciplines over the period 1997-2003.[6]

Overseas ranking systems of university performance also rely heavily on citations to measure the research performance of tertiary institutions. One of the more prominent examples is The Times Higher Education Supplement 200 index (which includes two New Zealand universities) which uses citations per staff member as a key measure of research performance (The Times Higher Education Supplement, 2006).

As a result of the numerous studies that have used bibliometrics to measure performance, there is now a degree of acceptance of citations as a proxy measure of quality.[7] For example, the New Zealand Vice-Chancellors Committee (NZVCC) has recognised the importance of using citations to measure performance. A recent report from the NZVCC (2006: p 24) stated that citations were "… a useful measure of a nation's research output". The report further stated that "…while the correlation between citation and research quality is not predictive, it is strongly positive, and citation rates per publication (or 'impact factors') are one of a range of indicators that can help identify 'the most widely cited ideas and individuals'. It is these ideas and individuals that will ultimately benefit New Zealand's social and economic development." (NZVCC, 2006: p. 25).

A further indication of the degree of acceptance of citations as a proxy measure of quality is that the proposed design of the system of measuring research quality in Australian universities, the Research Quality Framework, includes the use of citations to help inform the peer assessment process (Research Quality Framework Development Advisory Group, 2006). However, it is made clear that the use of metrics is to help inform peer reviewers and not to replace their judgement.[8]

While citations have become an increasingly common measure of research performance, there are reservations about their use and the results presented in this analysis need to be considered in the light of these caveats. Some of the most important (but by no means all) caveats are:[9]

- The coverage of the social sciences and humanities in the Thomson Scientific database – the most commonly used source of citations data - is not as extensive as coverage of the natural and medical sciences. In addition, publishing conventions in disciplines such as humanities and social sciences may favour research outputs such as books and book chapters which are not captured in the Thomson database.

4 An online searchable bibliometric tool maintained by Thomson Scientific.
5 See Ministry of Research, Science and Technology (2001, 2004, 2006a).
6 See Ministry of Research Science and Technology (2006b).
7 Smith and Eysenck (2002) and Norris and Oppenheim (2003) found a high degree of correlation between citations rates and the peer-assessed quality grades assigned in the 2001 Research Assessment Exercise in the disciplines of psychology and archaeology, respectively.
8 The United Kingdom government briefly considered replacing the peer review process in the 2008 Research Assessment Exercise with a system based solely on metrics. However, it was decided following consultation with the tertiary education sector to continue with a peer assessment approach for the 2008 round.
9 A fuller discussion on the issues surrounding the use of citations to measure research performance can be found in Coryn (2006) and the Research Evaluation and Policy Project (2005).

- Because citations are a better measure of science and medicine research impact, we need to take care when comparing performance. For instance, it isn't appropriate to compare raw citations scores among disciplines. Nor is it appropriate to draw conclusions from a comparison of citation rates among research organisations without allowing for the balance of the disciplines in which the organisations conduct research.

- The Thomson Scientific database is mostly made up of English language journals based in North America and Europe. As such, research in local journals that may be of a high impact will be excluded from the Thomson Scientific database, while citations in articles that appear in journals not indexed by Thomson Scientific are overlooked. In New Zealand, this may be a greater problem for applied fields of research and for research in the social sciences, where the research may be more focused on local problems and hence more likely to appear in local journals.

- Some of the citations may in fact refer to the source article in a negative way, meaning that some cites reflect a low opinion of the quality of the research. However, it is estimated that only around 7 percent of citations are negative (Bayers, 2007).

Therefore, it is important to note that this measure of research impact is not capturing the full research output of the universities or all of its impact. Indeed, one of the considerations for basing New Zealand's performance-linked research funding system on a mixed system of peer assessment and performance indicators was that some of the common metrics – such as citations – could lead to distortions. However, so long as the caveats surrounding the use of citations are well understood and the results of citation analysis are interpreted in the right context, they provide a useful measure of research performance, complementing PBRF scores and other metrics. This is especially true since bibliometric databases can be updated on an ongoing basis.

4 Measuring research impact

This section describes the bibliometric database used to generate the measure of research impact used in this study. This involves an explanation of the extent of the coverage of the dataset and how the data has been constructed. This is followed by a discussion of the specific measure of research used in this study and a rationale for its use.

4.1 Data

The data source for this bibliometric analysis is the Thomson Scientific New Zealand De-luxe dataset. This dataset captures citations that were assigned to research publications listed in the database between 1981 and 2005. The dataset covers around 10,000 journals across the sciences, social sciences, arts and humanities. Although it does not capture all research journals, it does capture the most significant peer-reviewed journals and so will include research which potentially has the greatest impact in the various fields.

The types of research publications included in the database are articles, notes, reviews, and proceedings papers. Other types of items such as editorials, letters, corrections, and abstracts have been omitted. A publication was assigned to an institution if at least one author was from that institution. If there were two authors from the same institution, the citations and papers were only counted once. However, where there are joint authors from different universities the publication is counted in the totals of each university. Therefore, there will be some double counting when generating university sector totals.

In generating this dataset, a major effort has been made to ensure that papers have been correctly assigned to institutions.[10] For example, where researchers may have referred only to a school of medicine rather than to the institution with which it is associated, the school will have been allocated to the correct university by using address information. Also, it is important to note that to allow consistent trend analysis, the publications that were produced by the colleges of education have been included in the university counts. Similarly, all papers produced by Wellington Polytechnic – which merged with Massey University in 1999 - have been assigned to Massey University.

The Thomson Scientific database used for this report categorises research papers into 106 subject areas. Given this large number of subject areas and the consequent relatively small number of publications in each, analysing each one individually over time is not feasible and there is a need to collapse the subject categories into a smaller number. The Ministry of Research, Science and Technology (2006) report analysing university bibliometrics used OECD subject classifications to assign papers into broad subject areas. However, in this report, the Thomson Scientific subject classifications are aligned with the subject areas of 10 of the PBRF subject panels.[11] Given the need to evaluate the impact of the PBRF over time, categorising the subject areas based on PBRF categories was deemed a more relevant approach.[12] In addition, by aggregating the data into fewer categories, the stability of the data is improved as a result of having a larger number of publications in each subject area to generate the relative citations figure.[13]

As Thomson Scientific can assign multiple subject categories to each publication (to a maximum of three) there will be an element of double counting when aggregating the papers into the PBRF panels. To give an idea of the scale of this issue, the total number of publications for the University of Auckland in the period 2001-2005 was 4,938. However, when summing the number of papers in each

10 The Ministry of Education has worked closely with Thomson Scientific to ensure that the research publications have been accurately assigned to the appropriate university.
11 See Tertiary Education Commission (2004), Table 2.1 p. 18. This describes the scope of each panel and explains how the panels are used in the PBRF assessment system.
12 A full list of the subject areas assigned to each PBRF panel can be found in the Appendix.
13 Aggregating the data in this way also has the advantage of reducing the impact of self-citations (Moed, 2005).

of the 106 Thomson Scientific subject areas, the total number of publications comes to 6,113. Therefore, the total number of publications at the University of Auckland is inflated by around 23 percent as a result of double counting. As this analysis is concentrating on the analysis of citations, this is less of a distortion than if the study was focused on the number of publications being produced by the universities.

As the Thomson Scientific subject areas are based on the subject area of the journals in the database, there will not be an exact match in the alignment of the research undertaken and the PBRF subject panels. This is especially the case in panels such as 'biological sciences' and 'medicine and public health'. The approach taken in this analysis is to assign those publications in Thomson' Scientific's clinical medicine subject areas to the 'medicine and public health' and 'health' panels where appropriate. All other biology-related publications have been assigned to the 'biological sciences' panel.

Note also that 'Māori knowledge and development' is omitted from this analysis as it cannot be determined which papers fall within this category. Also, 'creative and performing arts' has been omitted due to the low number of papers in this subject area in the Thomson Scientific database.

This method of aggregating narrow subject areas into PBRF panels has the disadvantage of masking the performance of universities in specific narrow areas. An example of this is Lincoln University, which achieved a relative impact of 0.5 in the 'biological sciences' panel in the period 2001-2005. However, in the narrow subject field of agriculture/agronomy, its relative impact was in fact 1.26. Therefore, to provide a detailed picture of the research performance of New Zealand universities, the relative impact of research in narrow subject areas for the period 2001-2005 is examined in section 6.

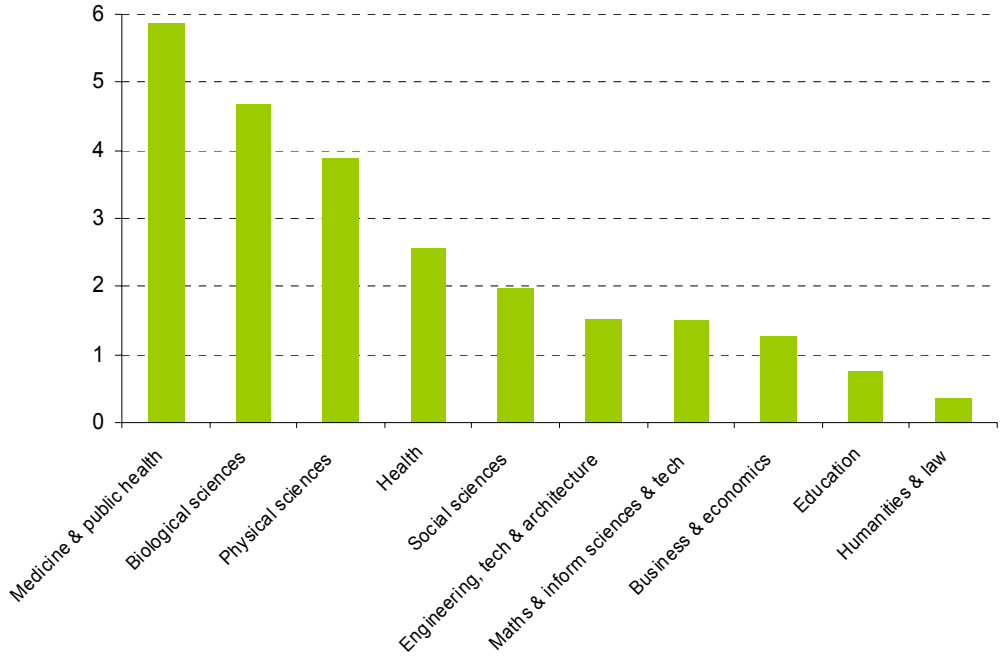
4.2 Relative research impact

This report uses a relative measure of citations per publication in five-year overlapping periods to measure research impact. In each five-year period, all the citations associated with publications newly listed in the Thomson Scientific database during that period are taken into account when generating the citations per paper measure.[14] Specifically, this report compares the average number of citations per paper achieved by New Zealand universities with the world average in the same subject area.

The reasons for using a relative measure of research impact are two-fold. Firstly, different subject disciplines have different rates of citation. Figure 1 presents the citations per paper for New Zealand universities for the period 2001-2005 across the 10 PBRF panels used in this report. As can be seen in Figure 1, the number of citations per paper varies significantly among subject disciplines. Papers in the medical sciences generally have higher rates of citation than other disciplines, such as education and the humanities. This difference would also be observed in other countries; because publishing conventions are different, citations of medicine papers will usually be significantly higher than for papers in the humanities. Therefore, it is not possible to compare the raw number of citations per paper across subject disciplines; for a meaningful comparison to be made, the measure needs to be normalised.

14 Citations to publications that were listed in the Thomson Scientific database prior to the start of a five-year window are not captured in this analysis.

Figure 1: Citations per publication for New Zealand university research by PBRF panel 2001-2005



Source: Thomson Scientific

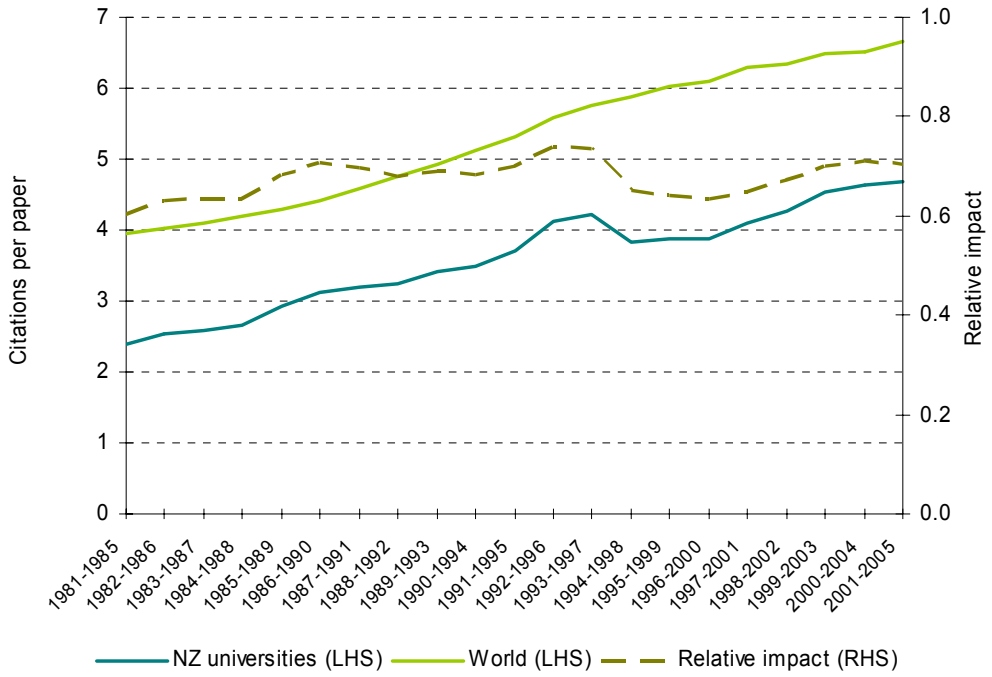
One way this can be done is to calculate the ratio of the citations per paper at a New Zealand university to the worldwide average of the citations per paper in that subject discipline.[15] This relative measure of research impact can then be compared across the various disciplines. A value greater than 1.0 indicates that the research impact is above the world average, while a value less than 1.0 indicates the impact was below the world average.

Secondly, normalising the citations measure in this way also helps to correct for the issue of citation inflation. Rates of citation are naturally rising over time as research activity grows worldwide and therefore simply comparing raw citations per paper scores over time will not necessarily identify if an improvement in research impact has occurred.[16] As an example, the citations per paper for New Zealand university research in the 'biological sciences' panel are presented in Figure 2. The overall trend shows an increase in the number of citations per paper over time, which might suggest that the impact of this research is rising. However, Figure 2 also shows that rates of citation were also rising worldwide. Therefore, it is hard to tell from the raw citations data whether the impact of the research has changed over time.

By generating the relative research impact, a clearer picture can be obtained of the change in research impact over time. The relative impact score of New Zealand university research in the 'biological sciences' displayed in Figure 2 suggests that the impact of university research in this area has not increased to the degree indicated by the raw citation rate. Therefore, by using a normalised measure, it is possible to more accurately identify if the impact of university research has either increased or decreased over time.

15 Adams and Smith (2006: p. 80) uses this approach.
16 As was the case in Ministry of Research, Science and Technology (2006b).

Figure 2: Citations per paper and relative research impact in the 'biological sciences'



Source: Thomson Scientific

The use of a normalised impact measure may result in several New Zealand universities achieving a relative research impact score of less than one. However, this does not necessarily indicate that there is a low level of research quality in these institutions, given that an analysis of the performance of United Kingdom tertiary institutions using a similarly constructed relative impact measure found that only around a quarter of institutions in most subject areas achieved scores above the world average (Adams and Smith, 2006).

5 Results by PBRF panel

In this section, the relative academic impact of research by New Zealand universities between 1981 and 2005 is examined. Firstly, the relative impact of research by the university sector as a whole is presented for the 10 PBRF panels that are used in this analysis. Then, an analysis of the relative impact of research by individual universities in each of the 10 PBRF panels is presented. Note that in the time series graphs presented in sections 5.1 and 5.2, a relative impact score of greater than 1 indicates that the academic impact of the research is above the world average.

5.1 The impact of university research by PBRF panel

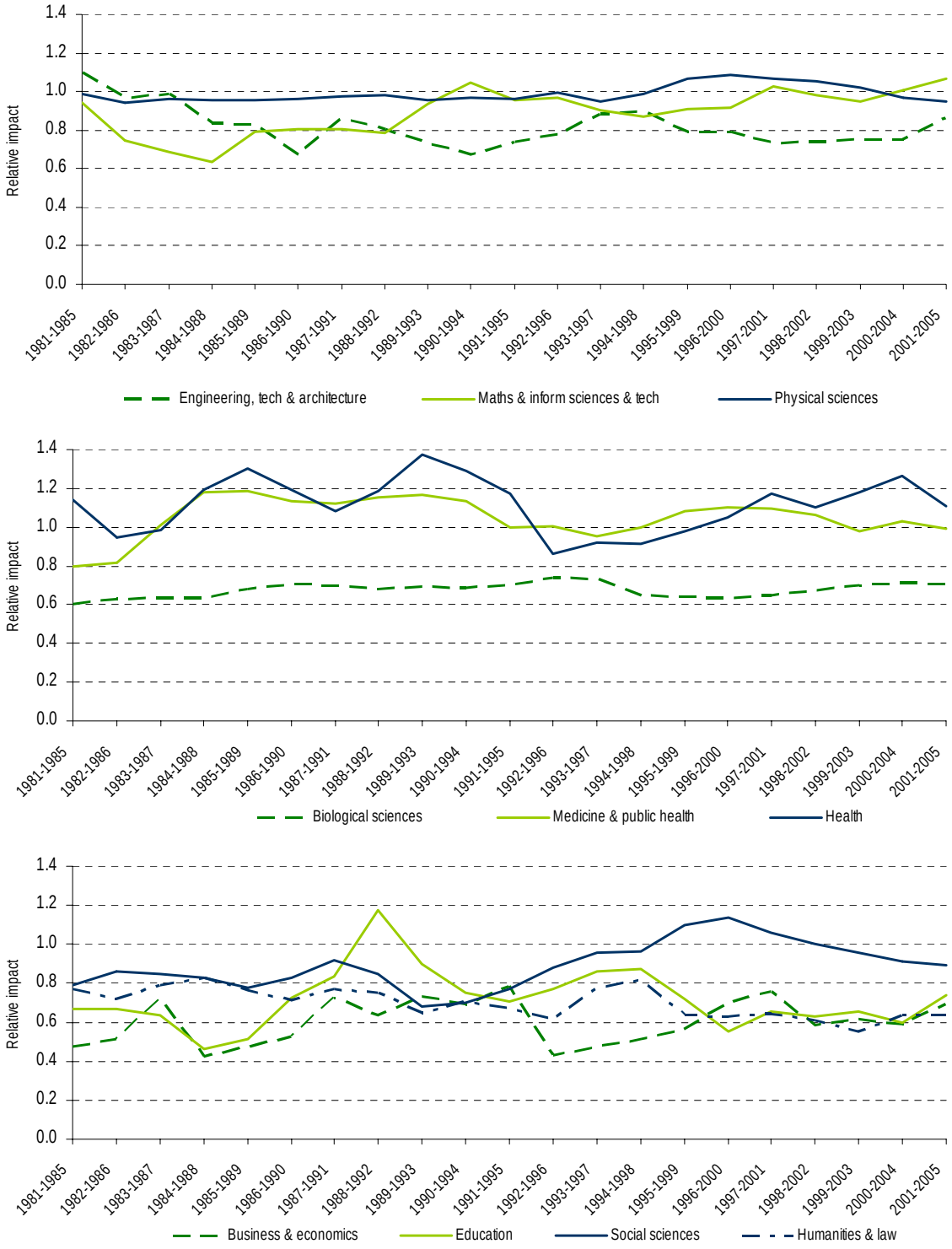
As can be seen in Figure 3, the relative impact of university research varies considerably both within and across panels over the period between 1981 and 2005. Research in the 'health' panel has had the greatest relative impact on the whole, with the relative impact being over 1.2 times that of the world average for significant lengths of time. 'Medicine and public health' was also well performing in that the research impact was above the world average for the majority of the time period. Overall, research in seven out of the 10 PBRF panels had a relative impact that was higher than the world average at some stage over the 25-year period of analysis, albeit some of them briefly. The highest relative impact of 1.37 was achieved by the 'health' panel (1989-1993), while the lowest relative impact of 0.42 was achieved by the 'business and economics' panel (1984-1988).

The variation within panels is significant, with a number of panels displaying an undulating pattern over time. For example, the 'social sciences' panel shows peaks in relative research impact in 1987-1991 and 1996-2000, and troughs in 1985-1989 and 1989-1993. The two PBRF panels with the greatest variation in relative impact are 'business and economics' and 'education'. This is not surprising, given that these two panels have the smallest number of articles listed in the Thomson database.[17] The most stable relative impact score was exhibited by the physical sciences panel, with a score that was close to 1.0 for the entire 25-year time period.

Over the last decade or so, panels that displayed a significant improvement in their relative impact in the period between 1993-1997 and 2001-2005 were 'business and economics' (46 percent), 'health' (20 percent) and 'mathematical and information sciences and technology' (18 percent). This compares with the 'humanities and law' panel, where relative impact fell by 18 percent. There were also smaller falls in the 'education' panel (14 percent), 'social sciences and other cultural/social sciences' (6.4 percent) and 'biological sciences' (4.1 percent).

17 For example, there were 483 papers listed in the database between 2001 and 2005 in 'business and economics', compared to 5,998 for 'medicine and public health'.

Figure 3: Relative impact of university research by PBRF panel

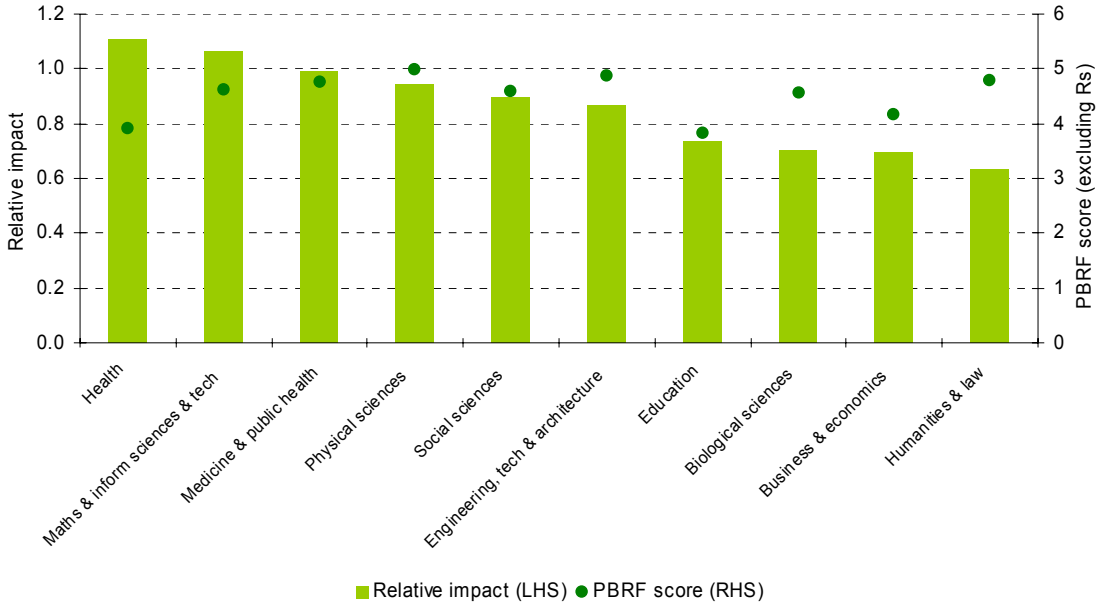


Source: Thomson Scientific

In the most recent five-year period (2001-2005), the 'health' panel achieved the highest relative impact of 1.11. This was followed by 'mathematics and information sciences and technology' (1.07) and 'medicine and public health' (0.99). The lowest relative impact of 0.63 was achieved by the 'humanities and law' panel.

Also included in Figure 4 is the average quality score achieved by New Zealand universities in the various panels in the 2006 PBRF Quality Evaluation. For the purpose of making the data more comparable, those researchers who were assigned an R quality category have been excluded.[18] Also, as the citations data treats all the universities as having merged with the colleges of education, the PBRF scores are constructed under the same assumption.

Figure 4: Relative impact of university research (2001-2005) and PBRF quality score (2006) by PBRF panel



Source: Thomson Scientific, Tertiary Education Commission

Comparing the relative impact with the average quality score shows that there are differences in the ranking of the PBRF panels. The 'health', 'humanities and law' and 'biological sciences' panels in particular exhibit quite distinct performance in the two measures. One of the reasons for the discrepancy in the measures in the 'health' panel is that the Thomson Scientific narrow subject areas do not include 'nursing', a subject with a low average quality score in the PBRF Quality Evaluation.

However, a comparison at this level of aggregation does not necessarily indicate the true level of relationship between citations and the PBRF average quality score. A more detailed analysis that compares the PBRF score with bibliometric data for individual universities is to be carried out in a forthcoming report.

18 The assumption here is that only those researchers who achieved at least a 'C' quality category are likely to have published in the journals indexed in the Thomson Scientific database.

5.2 The impact of individual university research by PBRF panel

In this section, the relative impact of research of individual universities within each PBRF subject panel is examined. Firstly, a time series analysis of the impact of research at universities over the period 1981-1985 to 2001-2005 is presented. For clarity of presentation, only those universities with a relatively large volume of papers in these subject panels have been included. However, all universities are included in graphs that show the impact of research in the most recent five-year period (2001-2005). For these graphs, the number of articles on which the relative impact measure is based is included in brackets after the university's name.[19]

5.2.1 Engineering, technology and architecture

The two universities with the highest volume of papers captured by the Thomson Scientific database in the 'engineering, technology and architecture' panel are presented in Figure 5.[20] The Universities of Auckland and Canterbury have well-established engineering schools; hence the relatively large number of research publications by staff at these two universities.

As can be seen in Figure 5, the relative impact of research at these two universities has followed the same general track over time. Both universities started the early 1980s with a relative impact around the world average, but then went through a period of general decrease in research impact. This decline in research impact continued until around the 1990-1994 period. The relative impact of research at these two universities peaked again around 1994-1998 at levels close to the world average, before once again falling. Since 1997-2001, both universities have exhibited a general improvement in the relative impact of their research. Over the full 25-year period, the highest relative impact of these two universities (1.10) was achieved by the University of Canterbury in 1981-1985.

Figure 5: Relative impact in 'engineering, technology and architecture' by selected university

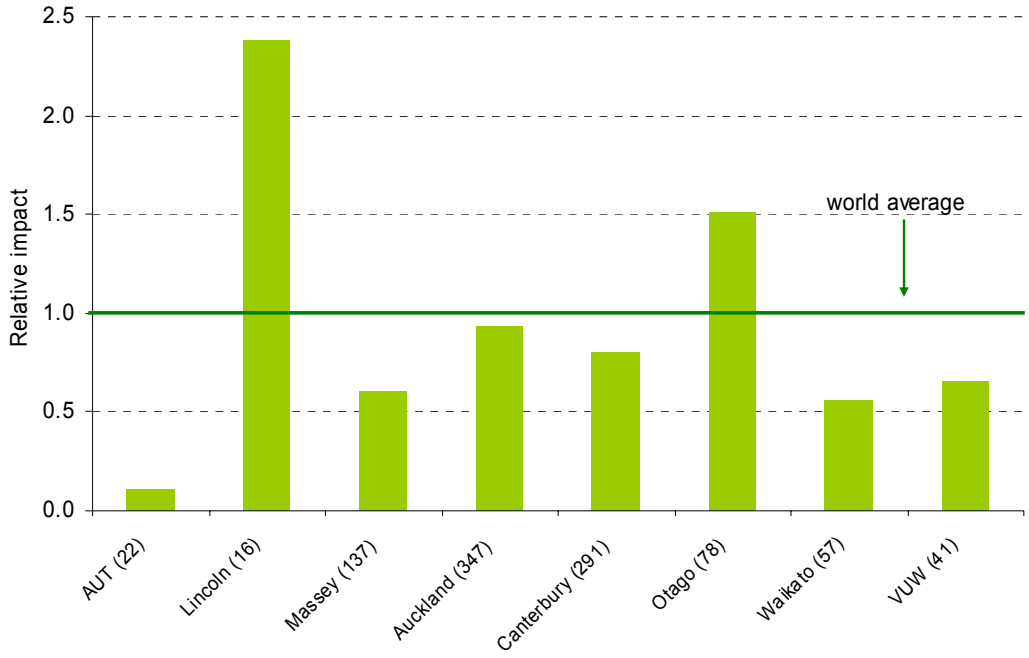
Source: Thomson Scientific

Figure 6 presents the relative research impact for all universities during the most recent five-year period (2001-2005). Research at Lincoln University had an impact over two times the world average, well above the other universities. This was a result of a high number of citations per publication in the narrow subject area of 'environment engineering/energy'. However, this strong result is tempered by the relatively small number of publications (16) on which this figure is based on. In a similar vein, the

19 Note that the issue of double counting will inflate the value of these counts.
20 The University of Auckland produced 35 percent and the University of Canterbury 29 percent of publications in this area at New Zealand universities in 2001-2005.

University of Otago achieved the second highest impact with a score of 1.51 but produced less than a third of the volume of papers produced by the Universities of Auckland and Canterbury.

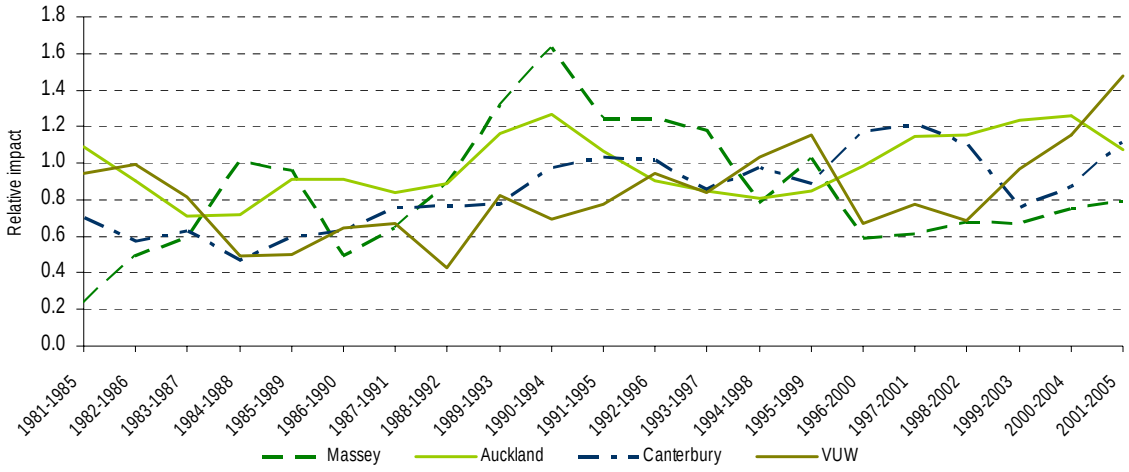
Figure 6: Relative impact in 'engineering, technology and architecture' by university 2001-2005



5.2.2 Mathematical and information sciences and technology

The relative research impact of the four universities with the largest number of publications in the 'mathematical and information sciences and technology' panel is presented in Figure 7. A key feature of Figure 7 is the large variation in the relative impact score for all four universities. An example of the scale of this variation is seen in the fact that Massey University achieved both the highest (1.63 in 1990-1994) and the lowest (0.24 in 1981-1985) relative impact score of the four universities included in Figure 7.

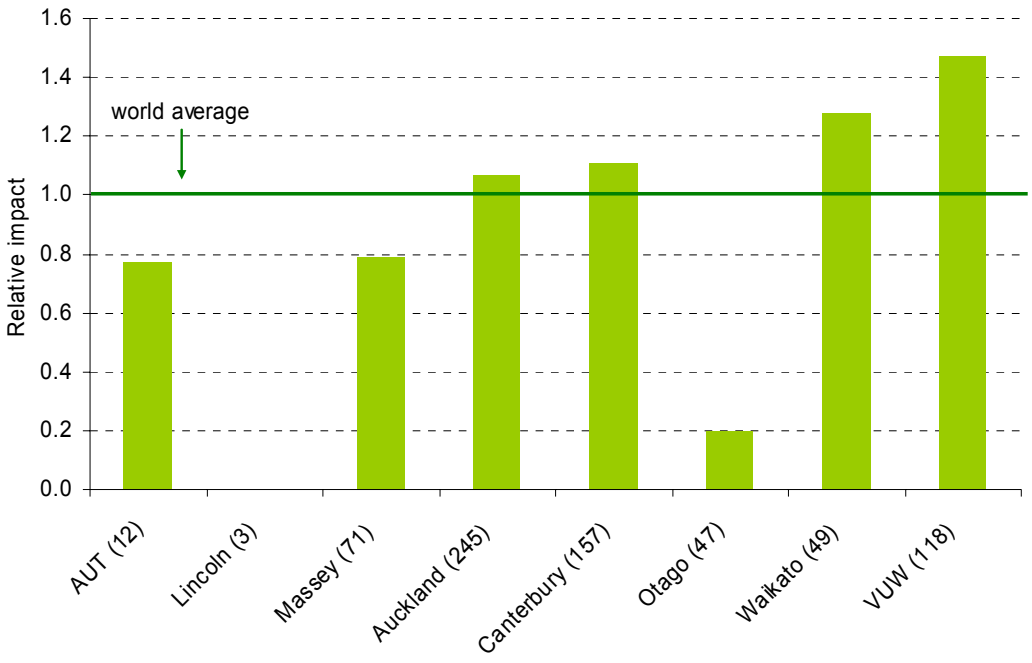
Figure 7: Relative impact in 'mathematical and information sciences and technology' by selected university



Source: Thomson Scientific

The relative impact of the research of all universities in the 'mathematical and information sciences and technology' panel in the most recent five-year period (2001-2005) is presented in Figure 8. Research at VUW achieved the highest relative impact score of 1.47 when all universities are considered. However, this high score is partly due to the impact of the strong performance in the narrow subject area of 'library and information sciences'.

Figure 8: Relative impact in 'mathematical and information sciences and technology' by university 2001-2005



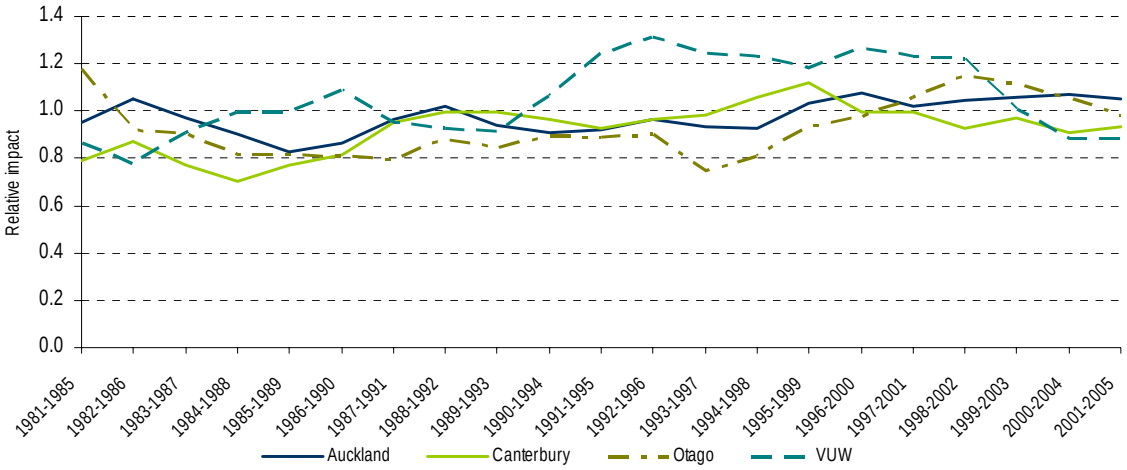
Source: Thomson Scientific

5.2.3 Physical sciences

The relative impact of research by the four universities with the largest volume of research publications captured by the Thomson Scientific database in the 'physical sciences' panel is presented in Figure 9. An examination of Figure 9 shows that the performance of these four universities was generally stronger in the second half of the 25-year period than the first.

The relative impact of research at VUW was over 1.2 times the world average for an extended period between the early 1990s and early 2000's. The most stable relative research impact over the last 25 years was exhibited by the University of Auckland.

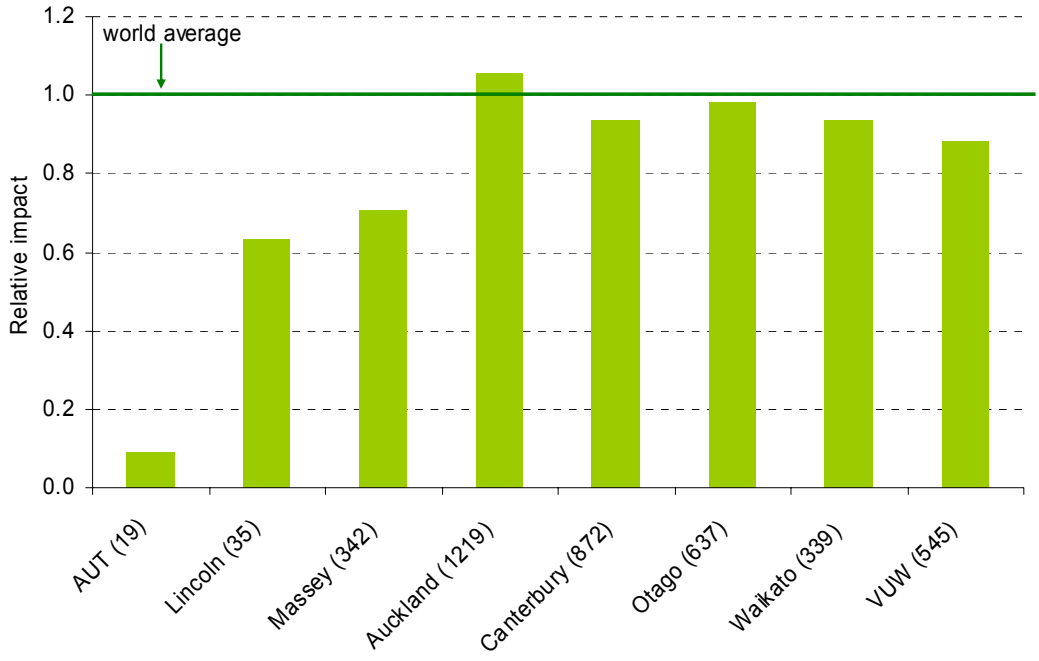
Figure 9: Relative impact in 'physical sciences' by selected university



Source: Thomson Scientific

The relative research impact, in the latest five year period (2001-2005), of all seven universities with publications captured in the Thomson Scientific database is presented in Figure 10. The highest relative impact score of 1.05 was achieved by the University of Auckland. However, it is noticeable that the performance of all the universities, with the exception of Massey University, Lincoln University and Auckland University of Technology is relatively close. In fact, this panel exhibited arguably the smallest variation in relative research impact during the most recent five-year period.

Figure 10: Relative impact in 'physical sciences' by university 2001-2005



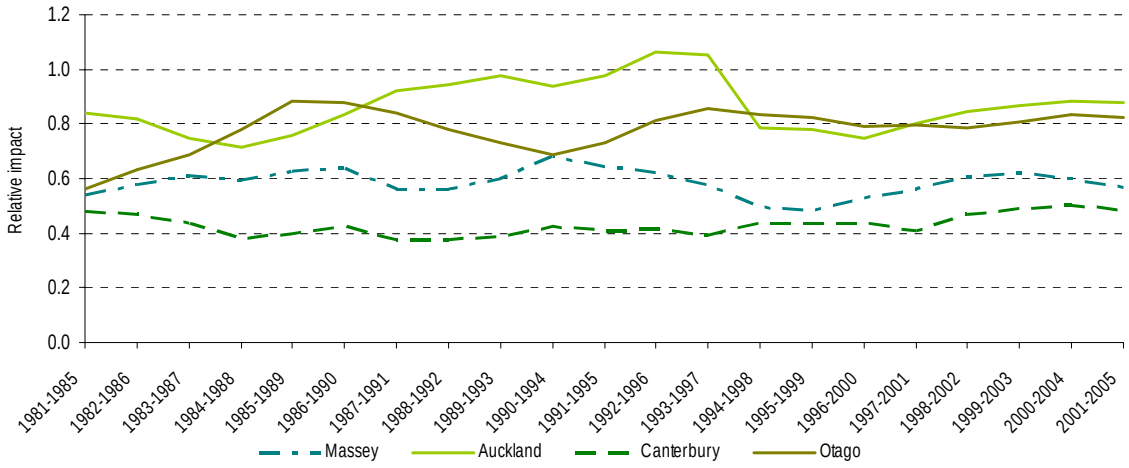
Source: Thomson Scientific

5.2.4 Biological sciences

Figure 11 displays the relative impact of research in the 'biological sciences' panel at the four universities with the greatest number of research publications between 1981 and 2005. Although the analysis in the previous section showed that the relative research impact for the combined universities was always below the world average (see Figure 3), the University of Auckland did in fact achieve a research impact score above the world average between 1991-1995 and 1993-1997.

Research at the Universities of Auckland and Otago had the greatest relative impact on average over the time period, with the highest relative impact of 1.06 achieved by the University of Auckland in 1992-1996. The research impact of the University of Canterbury was the most stable over time, although it was of a level below that of the three other universities included in Figure 11.

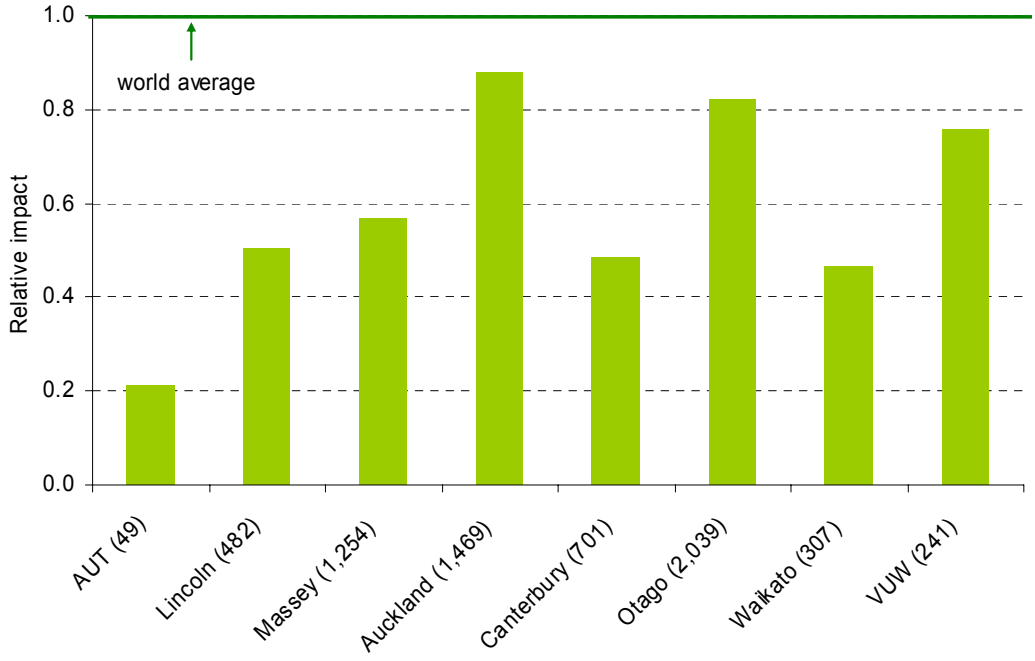
Figure 11: Relative impact of research in 'biological sciences' by selected university



Source: Thomson Scientific

The relative impact of research for all universities in the period 2001-2005 is presented in Figure 12. The picture remains much the same as in Figure 11 above. The University of Auckland and University of Otago achieved the highest relative impact for research in the 'biological sciences'. However, with the inclusion of all universities VUW achieved the third highest relative impact score in the five-year period. However, this score was achieved from a relatively small volume of research compared with the other universities.

Figure 12: Relative impact of research in 'biological sciences' by university 2001-2005

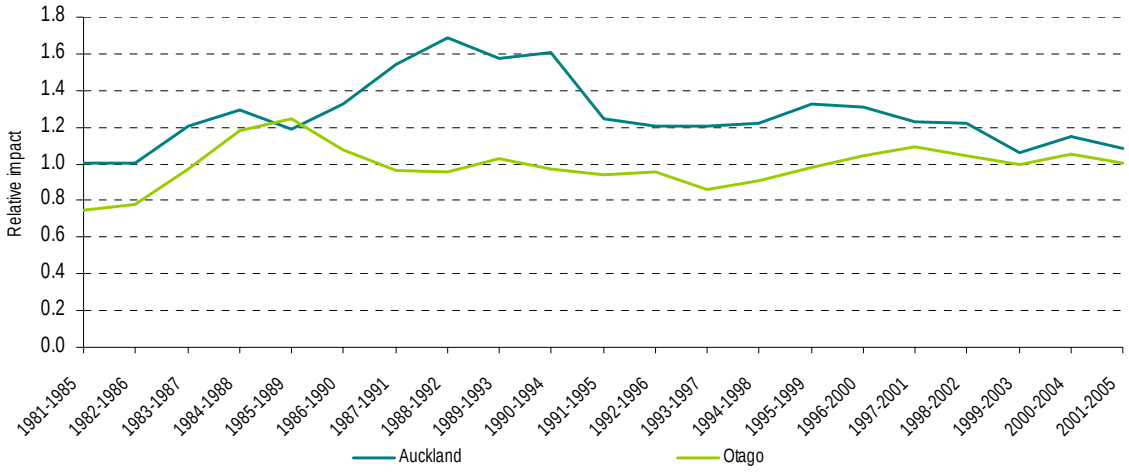


Source: Thomson Scientific

5.2.5 Medicine and public health

The two universities with medical schools attached to them, Auckland and Otago, dominate the volume of publications captured in the Thomson Scientific database in the 'medicine and public health' panel. As shown in Figure 13, the relative impact of research by the University of Auckland has at times reached over 1.6 times the world average. However, the relative impact of research at the University of Auckland has also been on a downward trend since reaching this high in 1988-1992. Nevertheless, the relative impact has remained above the world average. The relative impact of research by the University of Otago has been more stable than at the University of Auckland, with the result that the gap in relative impact between the two universities has narrowed considerably in recent years.

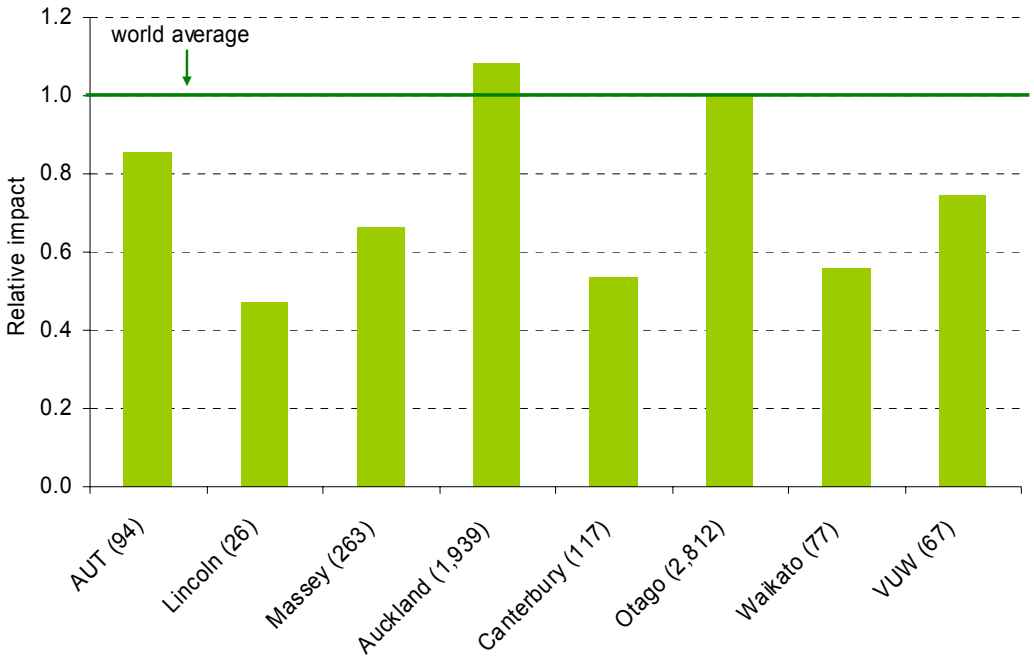
Figure 13: Relative impact in 'medicine and public health' by selected university



Source: Thomson Scientific

As can be seen in Figure 14, when the remaining universities are included in the analysis for the most recent five-year period (2001-2005), the Universities of Auckland and Otago are still ranked one and two, respectively. The third best performing university in this area is AUT.

Figure 14: Relative impact in 'medicine and public health' by university 2001-2005



Source: Thomson Scientific

5.2.6 Health

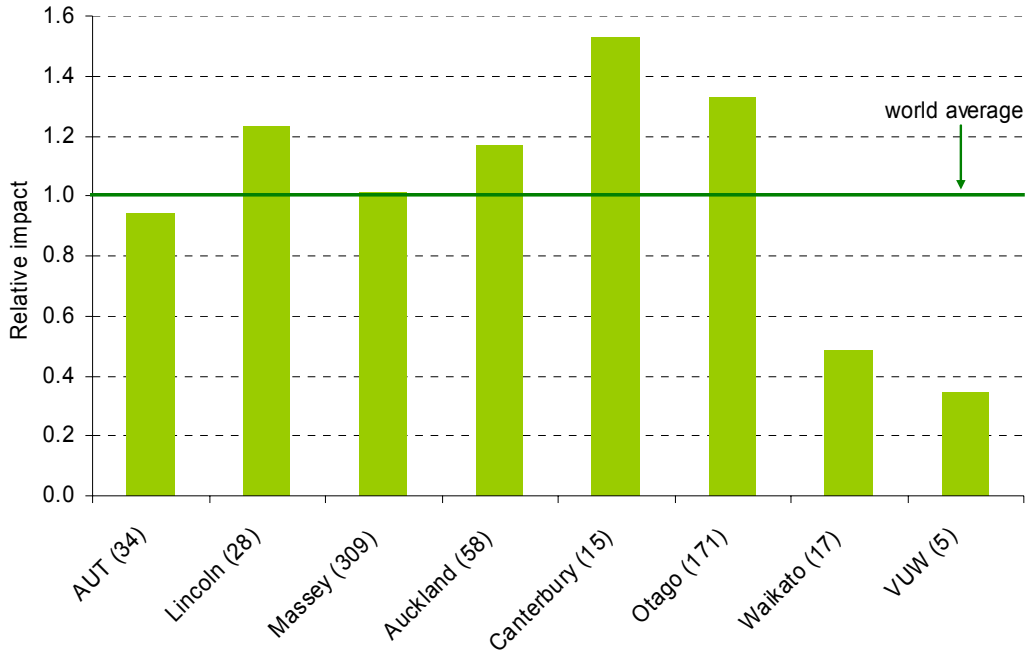
Overall, 'health' was the best performing of the 10 PBRF panels over the 25-year period. Of the two universities with the majority of the research publications captured by the Thomson Scientific database in this area, both the University of Otago and Massey University exhibited strong relative performance. It is also apparent in Figure 15 that from the mid-1980s the relative impact of research at the two universities has tracked along a somewhat similar path, although in recent years the relative impact of research at the University of Otago has been above that of research at Massey University. The University of Otago achieved its highest relative impact of 1.62 in 2000-2004 while the highest relative impact achieved by Massey University was 1.34 in 1990-1994.

Figure 15: Relative impact in 'health' by selected university

Source: Thomson Scientific

The relative impact of research by all universities in the 'health' panel over the most recent five-year period is presented in Figure 16. It shows that universities that produced more than just a handful of papers during the period were all close to, or exceeded, the world average. The highest impact was achieved by the University of Canterbury, but it only produced relatively few publications (15) compared with Massey University (309) and the University of Otago (171). Lincoln University also achieved a relatively high impact score of 1.23, but once again the volume of papers captured by the Thomson Scientific database was much smaller than that of the University of Otago and Massey University.

Figure 16: Relative impact in 'health' by university 2001-2005

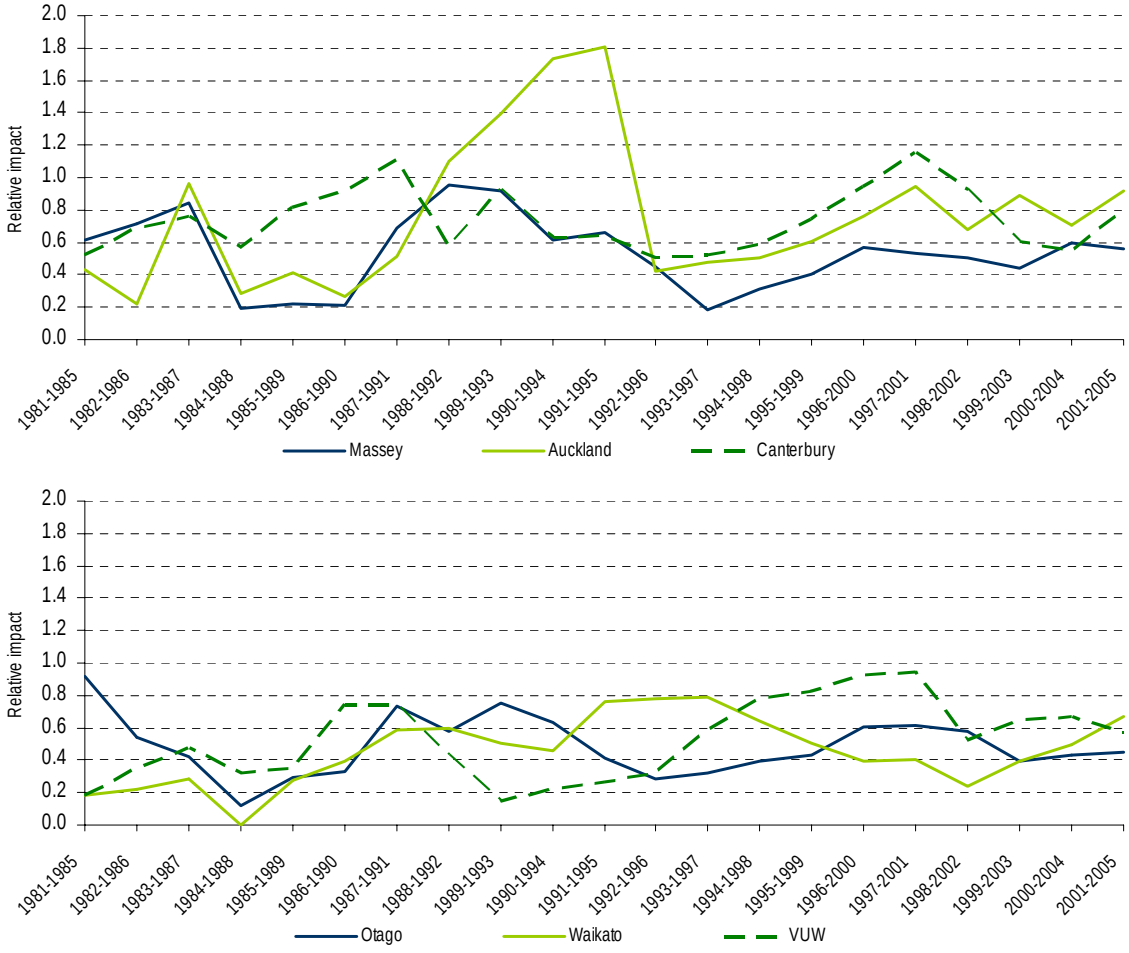


Source: Thomson Scientific

5.2.7 Business and economics

In the 'business and economics' panel, research at the University of Auckland had the highest relative impact overall. A noticeable feature of Auckland's performance was the high relative impact score achieved during the late 1980s and early 1990s. The relative impact value of 1.81 achieved by Auckland in 1991-1995 was one of the highest values attained by any university in any of the panels. However, it fell to 0.42 in the following year, presumably as the highly cited papers dropped out of the analysis. Because of the smaller number of publications in this panel, it is likely that one or perhaps two very highly cited papers were a major factor in the high variation in relative impact scores achieved by Auckland during this period.[21] The University of Canterbury was the other university to achieve a relative impact higher than the world average when it achieved a highest relative impact of 1.15 in 1997-2001.

Figure 17: Relative impact in 'business and economics' by selected university

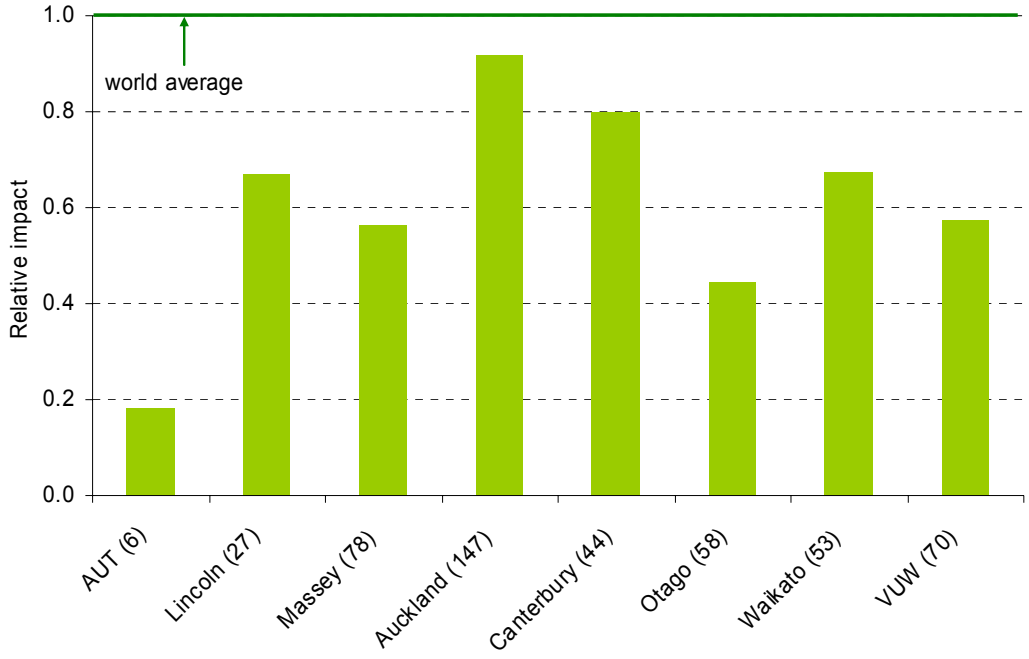


Source: Thomson Scientific

In the most recent five-year period (2001-2005), the University of Auckland achieved the highest relative impact score for its research with a score of 0.92. It was followed by the University of Canterbury (0.80) and the University of Waikato (0.67).

21 The rule of thumb is that around 20 percent of papers attract 80 percent of the citations (Bayers, 2007). Therefore even in some areas with a higher number of papers, a few highly cited papers can have a substantial impact on the relative impact.

Figure 18: Relative impact of research in 'business and economics' by university 2001-2005



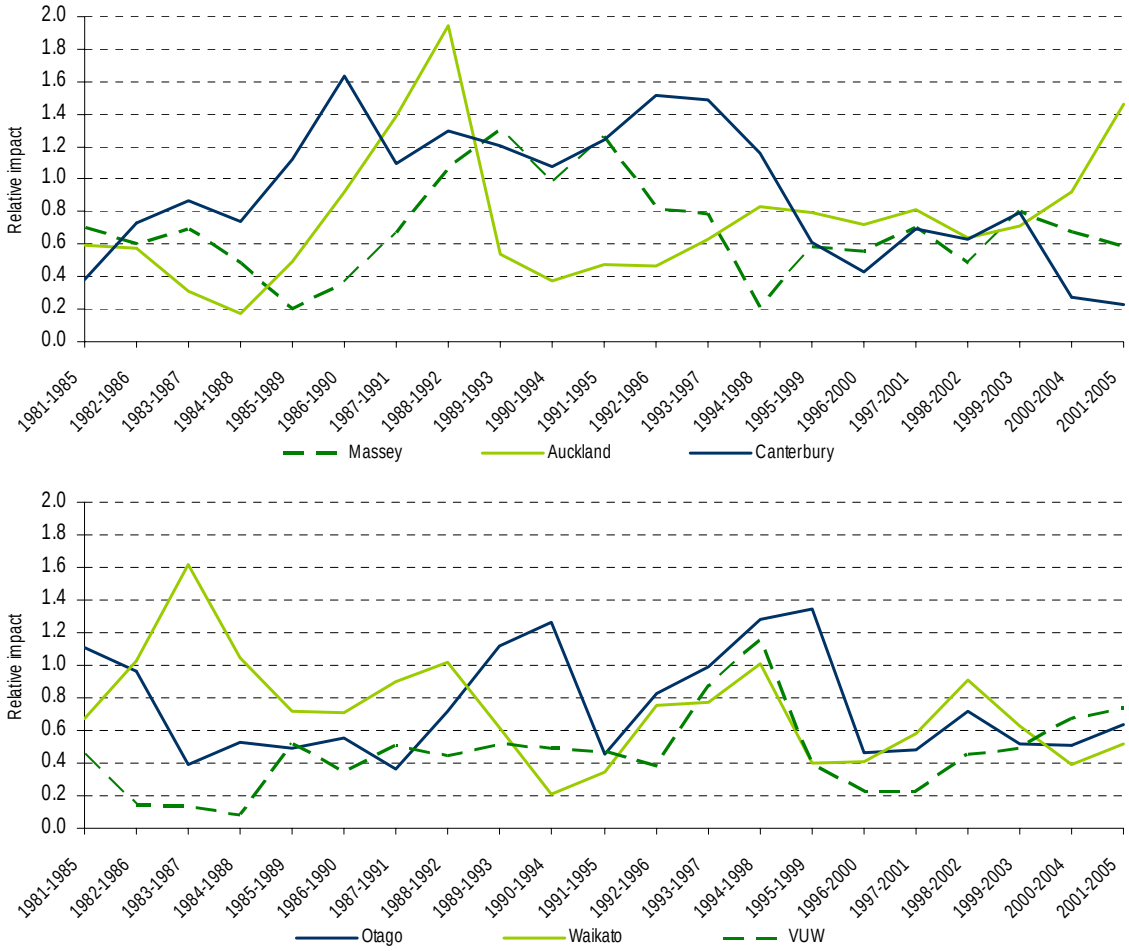
Source: Thomson Scientific

5.2.8 Education

Although the number of research publications is relatively small compared with some of the other panels, the relative impact of research in the 'education' panel has at times been well above the world average at various universities. In particular, the University of Auckland has at times produced research with very high relative impact. For example, in 1998-2002 the university achieved a relative impact score of 1.94, one of the highest scores recorded across all the panels. The University of Canterbury achieved the longest period of time with research impact above the world average in a period between the mid-1980s and the mid-1990s.

As in the 'business and economics' panel, one effect of the relatively small number of publications is that the relative impact of research in this area can show significant variation. This is especially the case where there are one or two highly cited publications. An example of this is the University of Auckland, where the research impact fell from 1.94 in 1988-1992 to 0.54 in the following period.

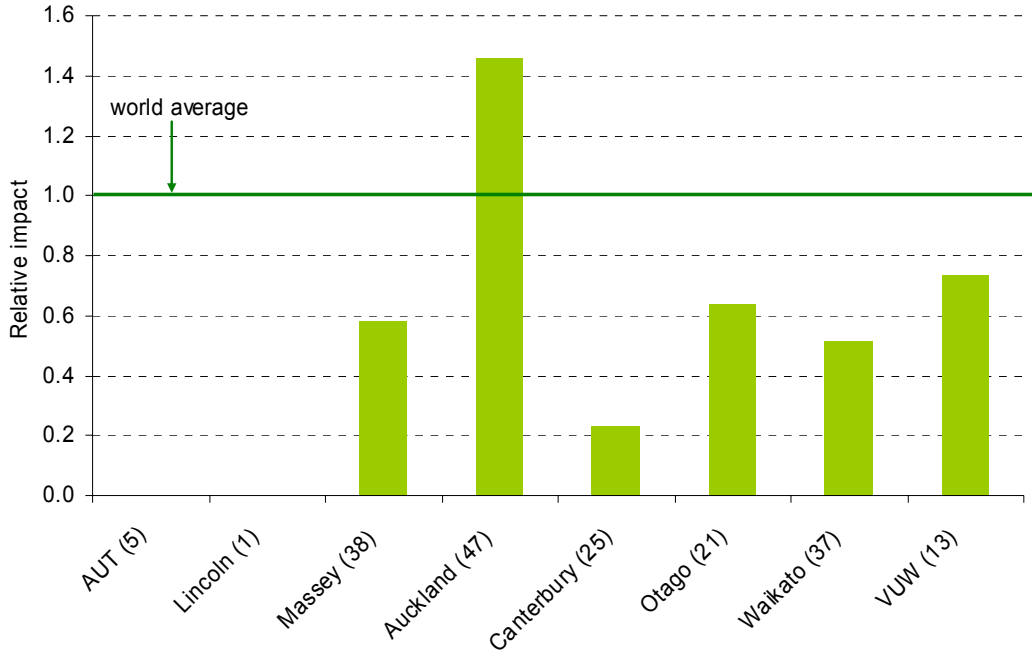
Figure 19: Relative impact in 'education' by selected university



Source: Thomson Scientific

In the most recent five-year time period (2001-2005), the University of Auckland produced the greatest volume of research captured in the Thomson Scientific database and produced research with a relative impact score (1.46) well above that of other universities.

Figure 20: Relative impact in 'education' by university 2001-2005

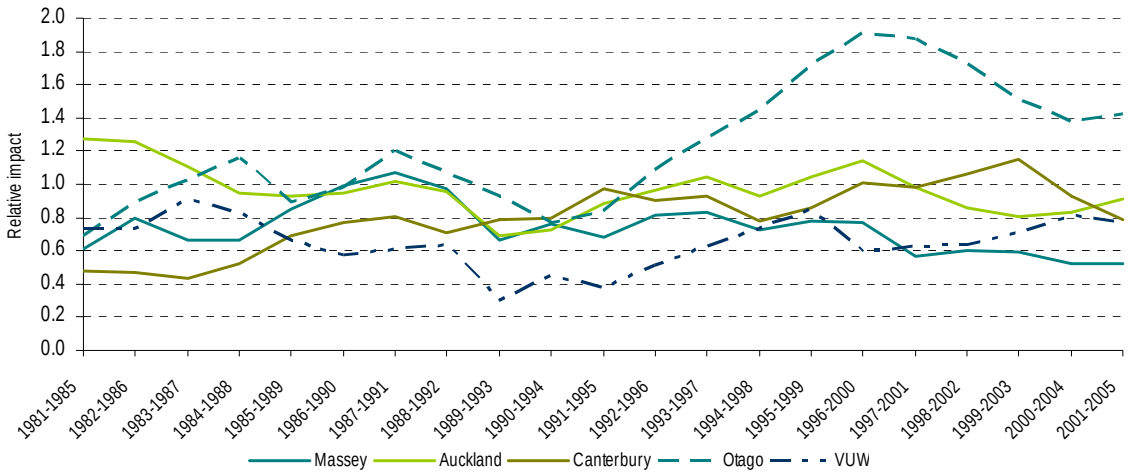


Source: Thomson Scientific

5.2.9 Social sciences and other cultural/social studies

The research for the five largest university producers of research publications captured in the Thomson Scientific database in the 'social sciences and other cultural/social studies' panel is presented in Figure 21 below. The most dominant feature of Figure 21 is the strong relative impact of research at the University of Otago. The relative impact score peaked for the University of Otago at 1.91 in 1996-2000 and has remained relatively strong since. For much of the period the impact of research at the University of Otago has been significantly above that of the other four universities that are displayed in Figure 23. However, this is in part due to the large number of publications in the 'psychology' narrow subject area at the University of Otago, which have a large number of citations and therefore boost the relative impact score compared with the other universities.

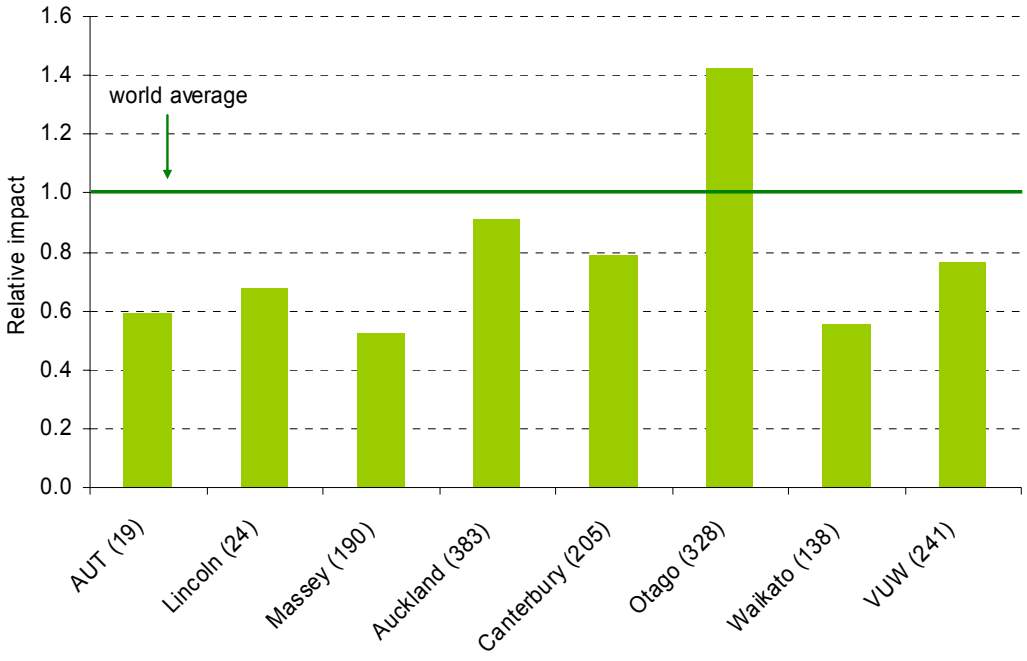
Figure 21: Relative impact in 'social sciences and other cultural/social studies' by selected university



Source: Thomson Scientific

The relative impact of all universities in the 'social sciences and other cultural/social studies' panel for the most recent five-year period (2001-2005) is presented in Figure 22. The strong relative impact of research at the University of Otago is again a feature, with it achieving a relative impact score of 1.42. This was significantly higher than the next highest relative impact score, which was achieved by the University of Auckland (0.91).

Figure 22: Relative impact in 'social sciences and other cultural/social studies' by university 2001-2005

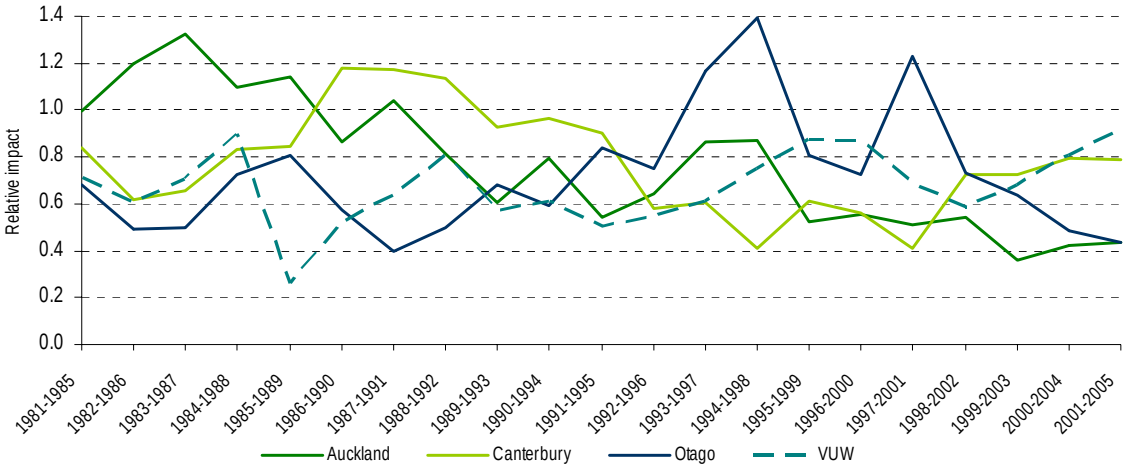


Source: Thomson Scientific

5.2.10 Humanities and law

The relative impact of research at the four universities with the highest number of publications captured in the Thomson Scientific database is presented in Figure 23. The highest relative impact score of 1.4 was achieved by the University of Otago in 1994-1998. The large variation exhibited by the universities in Figure 23 is partly due to the relatively small number of publications.

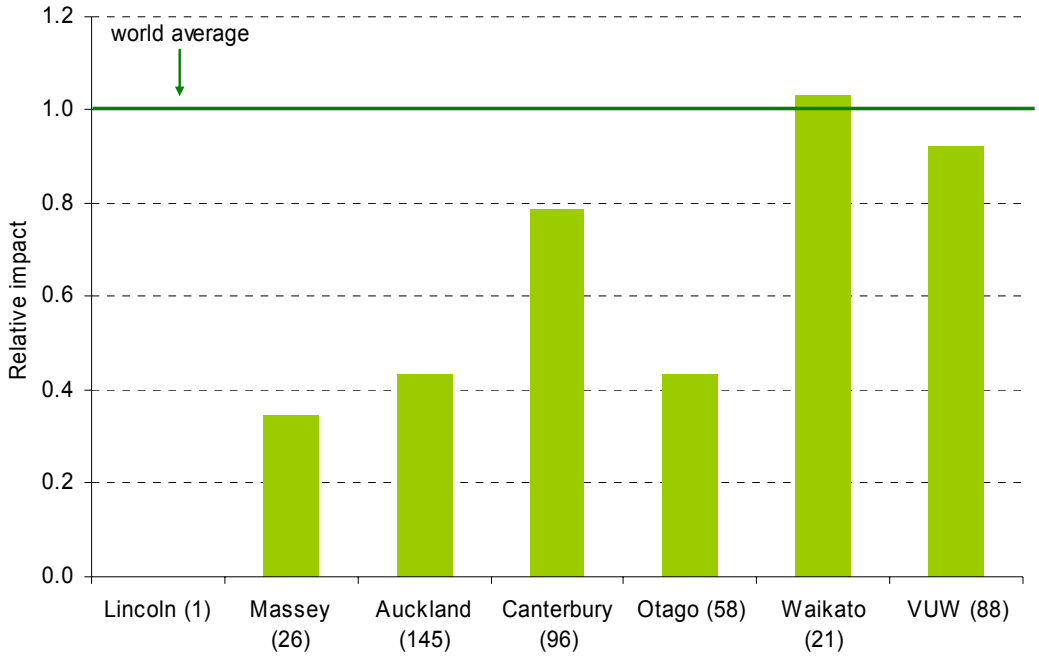
Figure 23: Relative impact in 'humanities and law' by selected university



Source: Thomson Scientific

The relative impact of research for all universities in the 'humanities and law' panel for the most recent five-year period (2001-2005) is presented in Figure 24. The University of Waikato achieved the highest relative impact of 1.03, although the volume of papers on which this measure is based on (21) is relatively small.

Figure 24: Relative impact in 'humanities and law' by university 2001-2005



Source: Thomson Scientific

6 Results by narrow subject area

Section 5 analysed the relative impact of university research by PBRF subject panel. A disadvantage of this approach is that aggregating the data into PBRF panels can mask the performance of the universities in narrow subject areas. Universities may have expertise in some quite specific areas. Therefore, this section analyses the relative impact of research produced in the most recent five-year period (2001-2005) in the narrow subject areas used by Thomson Scientific.

To avoid any distortion in the relative impact measure caused by small numbers of publications, only those narrow subject areas with more than 25 publications listed in the Thomson Scientific database in the five-year period have been analysed. In each of the graphs in this section, the number following the narrow subject area name refers to the number of publications that were listed in the Thomson Scientific database during the 2001-2005 period.

For clarity of presentation, only the top 30 narrow subject areas in terms of relative research impact are displayed on the graphs of publications in narrow subject areas. However, the data for all the narrow subject areas can be found in Appendix A.

6.1 The impact of university research by narrow subject area

Figure 25 presents the relative impact of research by New Zealand universities, ranked in order from highest to lowest, by narrow subject area for the period 2001-2005. Thirty-nine percent of the 97 narrow subject areas displayed in Figure 25 have a relative impact above the world average.[22]

The highest relative impact score of 2.6 was achieved in the narrow subject area of geological/petroleum/mining engineering. This was followed by 'language and linguistics' (1.82) and 'optics and acoustics' (1.75).

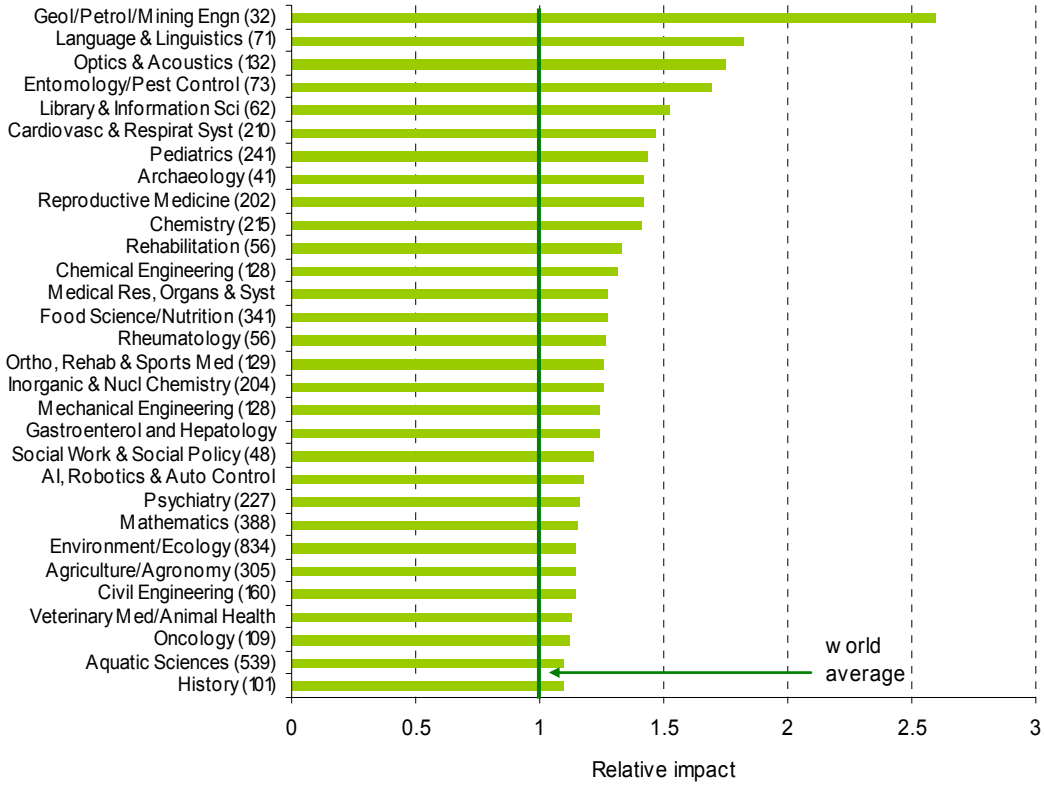
The area of medicine is well represented in those narrow subject areas with a relative impact above the world average - 11 out of the 38 narrow subject areas with relative impact scores above one were in this area. The medical areas with the highest relative impact were 'cardiovascular and respiratory systems' (1.47), 'paediatrics' (1.44), and 'medical research, organs and systems' (1.28).

Although the traditional sciences and medical sciences tend to dominate those subjects with a relative impact score above one, there are some subject areas from the humanities and social sciences that also achieve this level of relative impact. In addition to 'language and linguistics', 'archaeology' (1.42), 'social work and social policy' (1.22), 'history' (1.1) and 'sociology and social sciences' (1.07), all achieved relative impact scores above one.

To illustrate the relative performances of the universities, Figure 26 presents the relative impact scores for each university in each narrow subject area where they have more than 25 publications recorded in the Thomson Scientific database in the period 2001-2005.

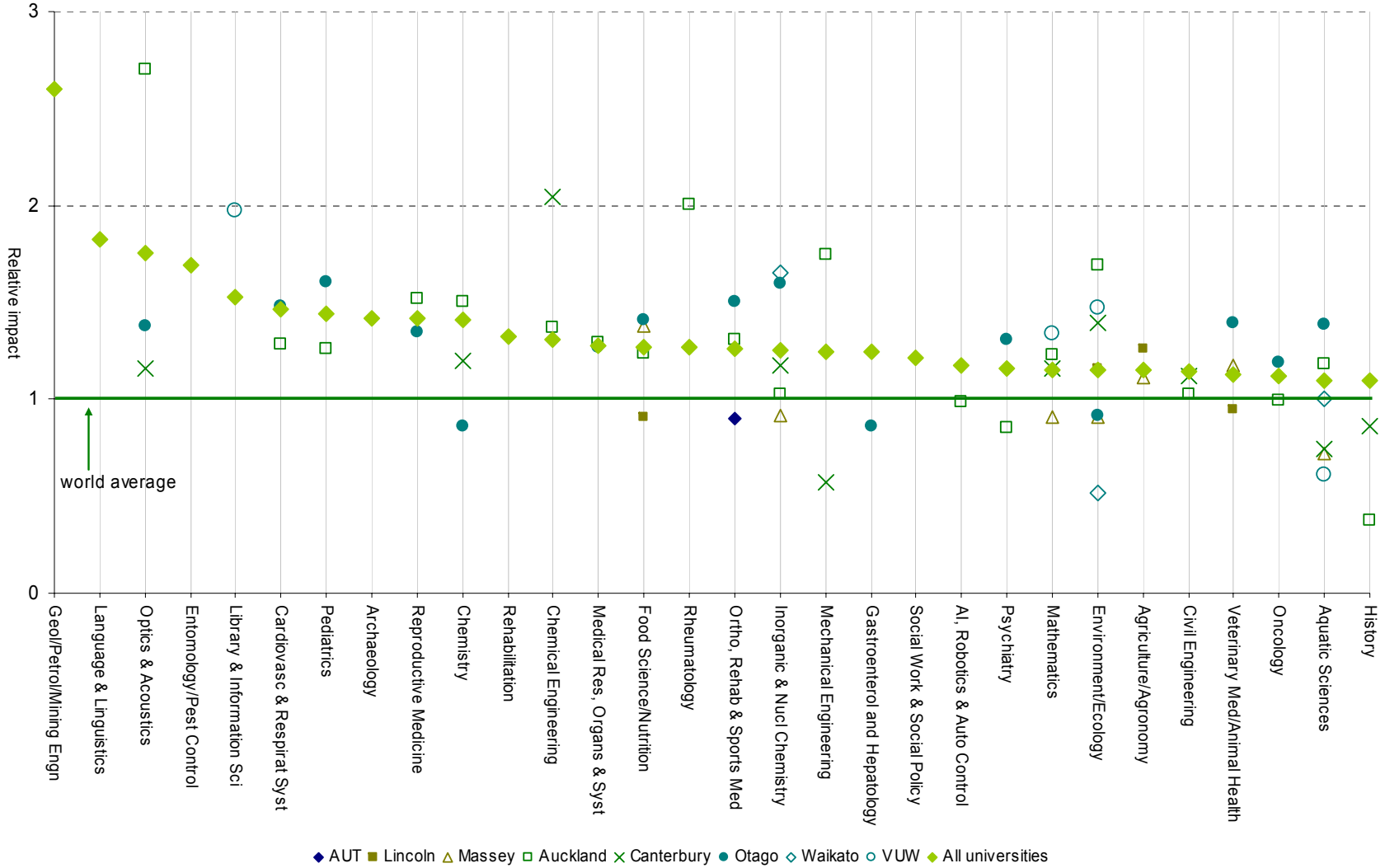
22 Thomson Scientific assigns papers to 106 narrow subject areas. However, only 97 of these narrow subject areas had more than 25 publications listed in the Thomson Scientific database during 2001-2005.

Figure 25: Relative impact of New Zealand university research by narrow subject area 2001-2005



Source: Thomson Scientific

Figure 26: Relative impact of research by individual university and narrow subject area 2001-2005

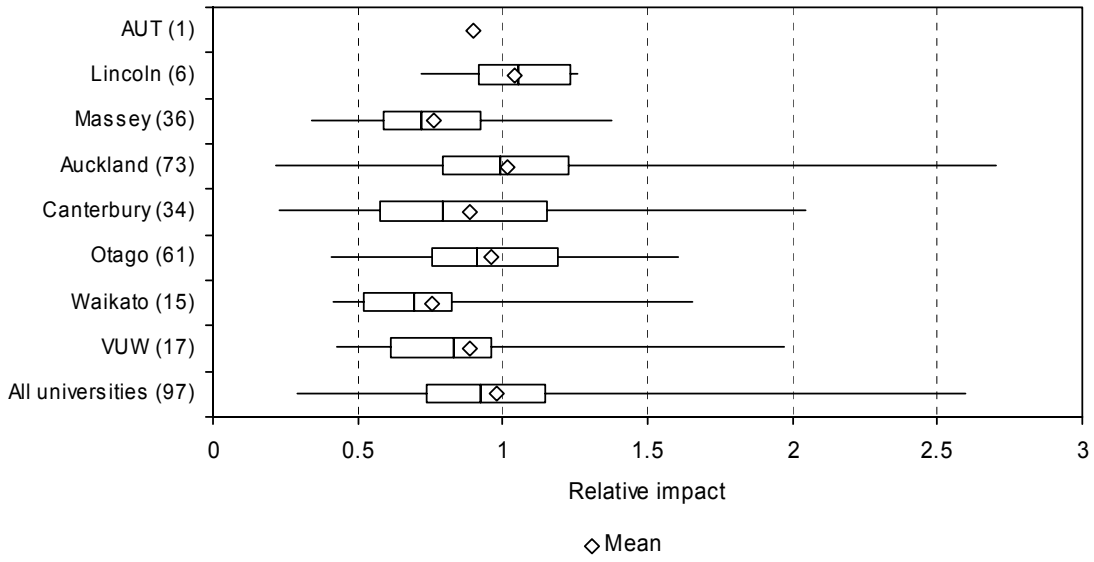


Source: Thomson Scientific

A sense of the overall performance of each of the universities can be gained from Figure 27. This presents boxplots of the relative impact scores of the universities in the narrow subject areas. The figure in brackets after the university name displays the number of narrow subject areas on which the statistics used to generate the boxplot were based.

The extended whiskers to the right, along with the means exceeding median relative impact scores, indicate that the relative impact scores are skewed to the right at the majority of universities. Lincoln University exhibits the highest mean and median relative impact scores – but this is based on data for just six narrow subject areas. The University of Auckland achieved the next highest mean and median relative impact score and exhibited the greatest variation in performance across the narrow subject areas. The University of Auckland also had at least 25 or more publications in the most narrow subject areas (73) than the other universities.

Figure 27: Distribution of relative impact scores by university 2001-2005



Source: Thomson Scientific

6.2 The impact of individual university research by narrow subject area

Section 6.1 examined the relative impact scores for the university sector as a whole. This section presents the relative impact scores for each university, making it easier to compare the narrow subject areas at each university and identify areas that have a high relative impact at that institution.

In this section, only those narrow subject areas with 25 or more publications in the period 2001-2005 are included in this analysis. This is to avoid the distortions that can arise where there is a small number of publications. For clarity of presentation, only the top 30 narrow subject areas in terms of relative research impact are displayed on the graphs of those universities with publications in narrow subject areas. However, the data for all the narrow subject areas at each university can be found in Appendix A.

6.2.1 Auckland University of Technology

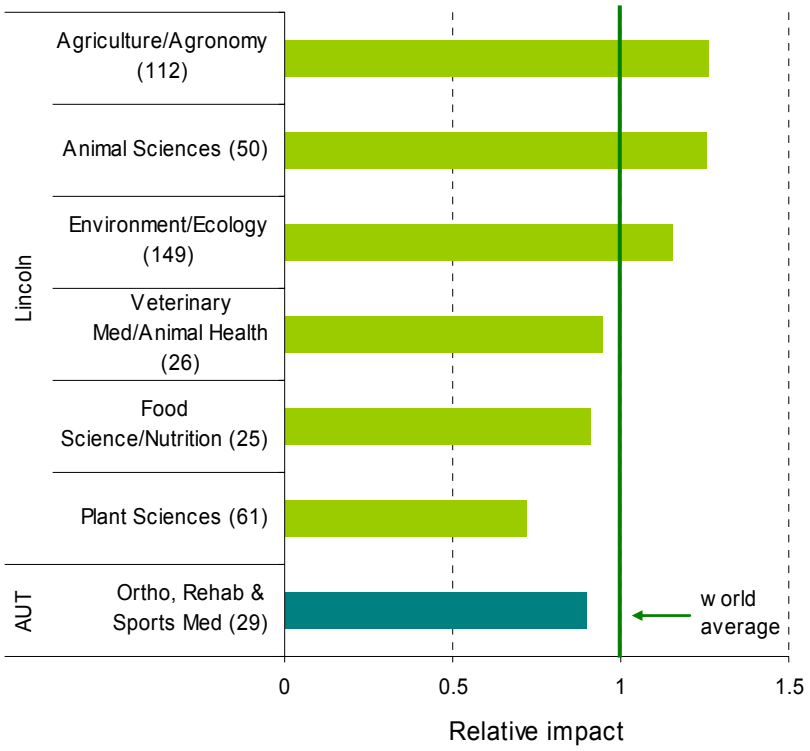
The relative impact of research at Auckland University of Technology (AUT) by narrow subject area is presented in Figure 28. At AUT, only one narrow subject area had a sufficient critical mass of publications to be included in this analysis. This was 'orthopaedics, rehabilitation and sports medicine', which achieved a relative impact score of 0.9. The fact that only one narrow subject area had enough publications to be included in this analysis is not surprising, given that AUT only became a university in 2000.

6.2.2 Lincoln University

The specialisation of Lincoln University in the land-based sciences is reflected in the narrow subject areas displayed in Figure 28. All of these six subject areas are related in some fashion to the land-based sciences. The fact that there are only six narrow subject areas with 25 or more publications in the most recent five-year period is partly a reflection of Lincoln's size; it is the smallest university by some margin.

Half of Lincoln's six narrow subject areas shown in Figure 28 achieved a relative impact score above one. The top two subject areas were 'agriculture/agronomy' and 'animal sciences' with relative impact scores of close to 1.2. This strong performance in the agricultural sciences was not reflected in Lincoln's performance in the 'biological sciences' PBRF panel and illustrates the masking of performance that can result from the aggregation of narrow subject areas into the broader PBRF subject panels.

Figure 28: Relative impact of research at Auckland University of Technology and Lincoln University by narrow subject area 2001-2005



Source: Thomson Scientific

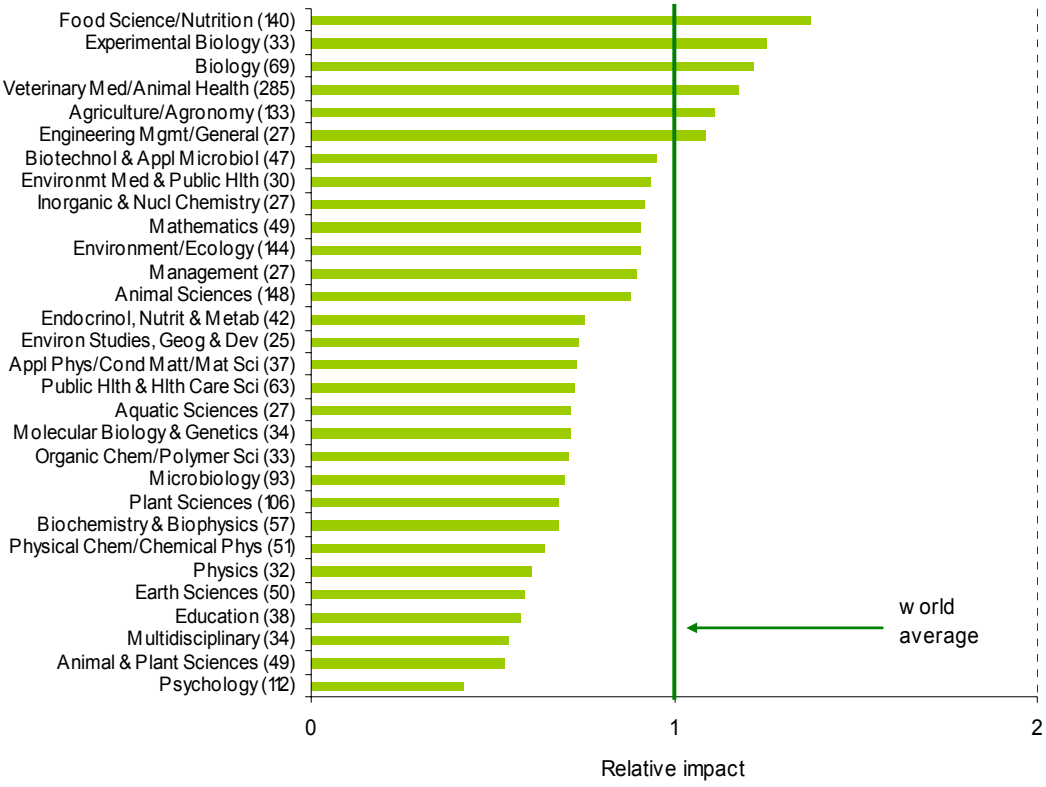
6.2.3 Massey University

Massey University has identified that its research strengths reside in the land-based and biological processing disciplines.[23] This is reflected in the fact that five of the six narrow subject areas that achieved relative research impact scores higher than one are in this broad subject area. Overall, 17 percent of the narrow subject areas with 25 or more publications had an impact above the world average, with the narrow subject area of 'food science/nutrition' achieving the highest relative impact score of 1.38.

Massey University also has the sole veterinary school in New Zealand which is reflected in the high number of publications listed in the Thomson Scientific database (285) in this area. The relative impact of research in 'veterinary medicine/animal health' was above the world average, with a relative impact score of 1.18.

23 http://sfp.massey.ac.nz/Library/Massey%20University%20Charter%202003-2011.pdf.

Figure 29: Relative impact of research at Massey University by narrow subject area 2001-2005



Source: Thomson Scientific

6.2.4 University of Auckland

The University of Auckland is New Zealand's largest university, which is reflected in the number of narrow subject areas (73) with 25 or more publications listed in the Thomson Scientific database in the latest five-year period. Overall, 47 percent of the narrow subject areas with more than 25 publications achieved a relative research impact above the world average.

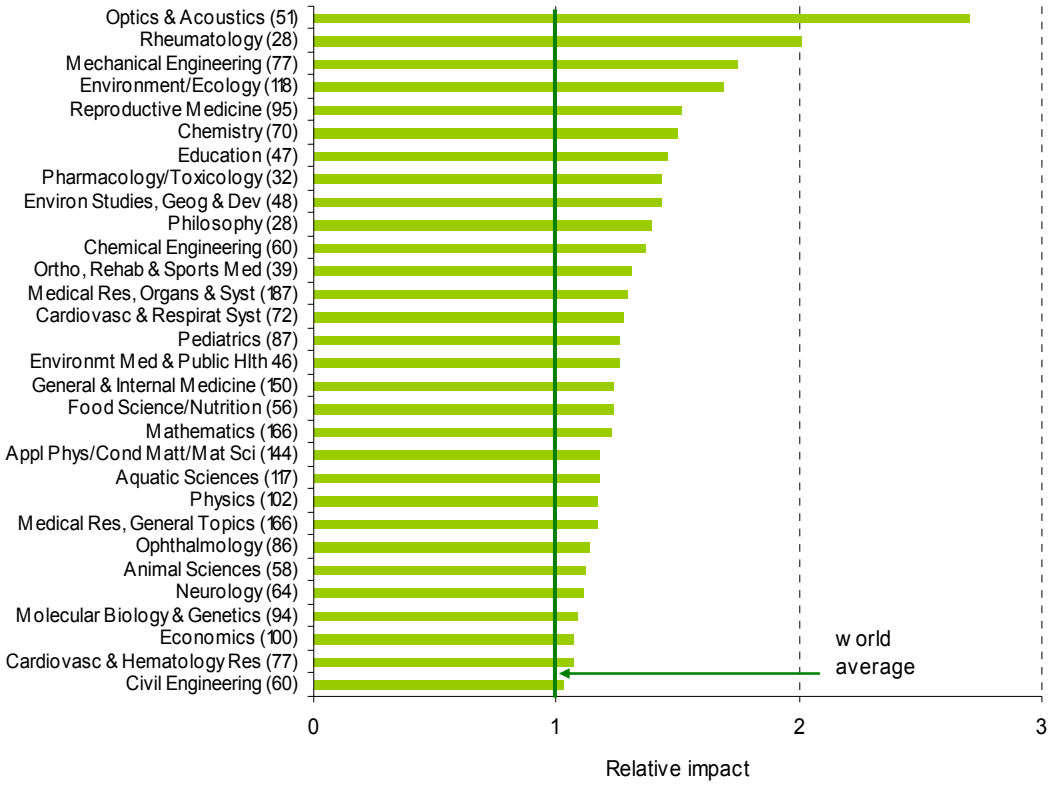
A large number of the narrow subject areas in Figure 30 are in the broad medical field, a reflection of the presence of one of New Zealand's two medical schools. The relative impact of research in this area was generally high, with 11 narrow subject areas in the medicine field achieving a relative research impact score above one. The top-performing narrow subject area in the medical sciences was 'rheumatology' with a relative impact score of 2.01. Also high performing was 'reproductive medicine' (1.52).

The University of Auckland also specialises in the field of engineering and has a long-established engineering school. Three narrow subject areas in the engineering field achieved a relative impact greater than one, with 'mechanical engineering' having the highest relative impact score of 1.75.

A narrow subject area in the physical sciences area, 'optics and acoustics', achieved the highest relative impact score of 2.7 at the University of Auckland. Other physical science subjects such as 'chemistry' (1.5) and 'physics' (1.17) also had a high relative impact.

More so than at the other universities, research in non-science and non-medical fields also achieved high relative impact scores. Two examples of this were 'education', with a relative impact score of 1.46, and 'philosophy', with a relative impact score of 1.39.

Figure 30: Relative impact of research at the University of Auckland by narrow subject area 2001-2005



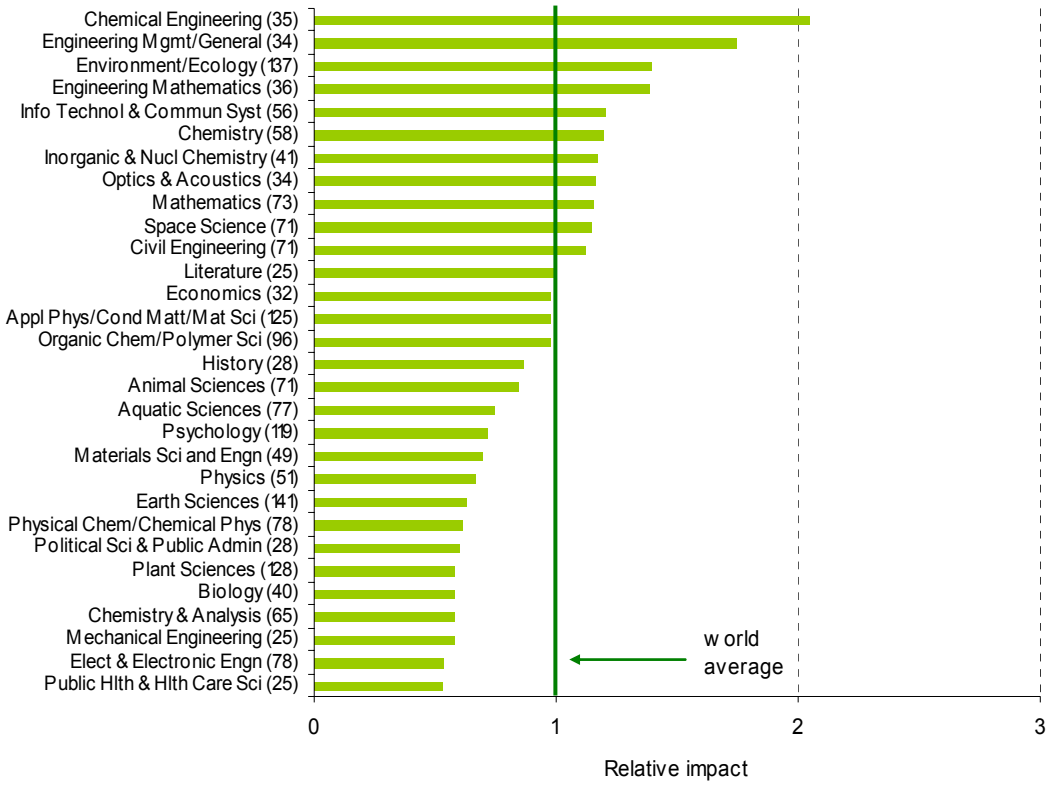
Source: Thomson Scientific

6.2.5 University of Canterbury

Twelve of the 34 narrow subject fields at the University of Canterbury with 25 or more publications listed in the Thomson Scientific database during the period 2001-2005 achieved a relative impact above the world average. The narrow subject area with the highest relative research impact at the University of Canterbury was 'chemical engineering' with a score of 2.05. Canterbury also achieved high relative impact scores in several other engineering narrow subject areas. These included 'engineering management/general' (1.75), 'engineering mathematics' (1.39) and 'civil engineering' (1.12).

In one notable difference from the other universities, Canterbury was the only university to have an area in the field of information technology with a relative impact above one; the 'information technology and communication systems' narrow subject area achieved a relative impact score of 1.21. The University of Canterbury also performed well in the narrow subject areas of 'chemistry' (relative impact score of 1.2), 'mathematics' (1.16) and 'space science' (1.15).

Figure 31: Relative impact of research at the University of Canterbury by narrow subject area 2001-2005



Source: Thomson Scientific

6.2.6 University of Otago

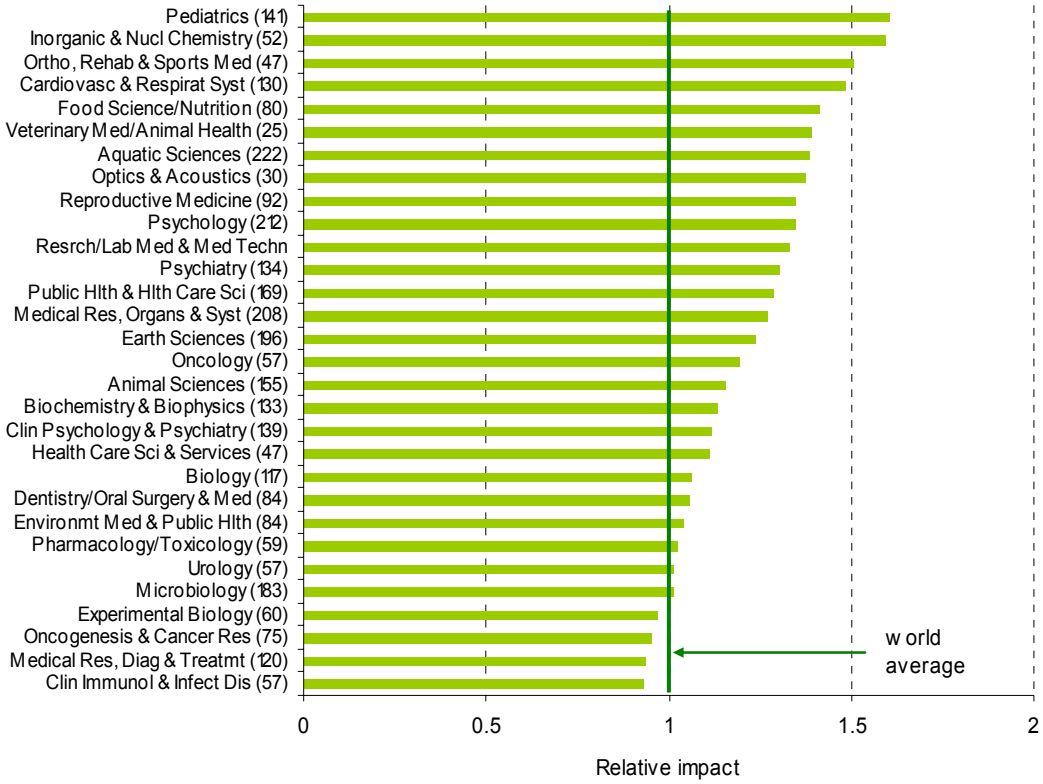
The University of Otago has the second largest research workforce among the New Zealand universities, a fact reflected in the large number of narrow subject areas with more than 25 publications listed in the Thomson Scientific database in the latest five-year period (2001-2005). Overall, 43 percent of the 61 narrow subject areas at the University of Otago had a relative impact above the world average.

As one would expect for a university with a medical school, many of the narrow subject areas in Figure 32 are in the medicine field – with a significant proportion of these achieving a relative impact score above one. One of these subject areas, 'paediatrics', achieved the highest relative impact score of 1.6 at the University of Otago. Other medical areas that performed well were 'cardiovascular and respiratory systems' (1.48) and 'reproductive medicine' (1.35).

The University of Otago also has specialist research areas in sports medicine and dentistry. In both of these areas, the relative impact of research was above the world average. The narrow subject area of 'orthopaedics, rehabilitation and sports medicine' attained a relative research impact score of 1.51 and 'dentistry/oral surgery and medicine' a relative impact score of 1.06.

Also of note is the high relative impact of research in the narrow subject areas of 'psychology' and 'psychiatry' – with relative impact scores of 1.35 and 1.31, respectively. The related narrow subject area of 'clinical psychology and psychiatry' also performed well with a relative impact score of 1.12.

Figure 32: Relative impact of research at the University of Otago by narrow subject area 2001-2005



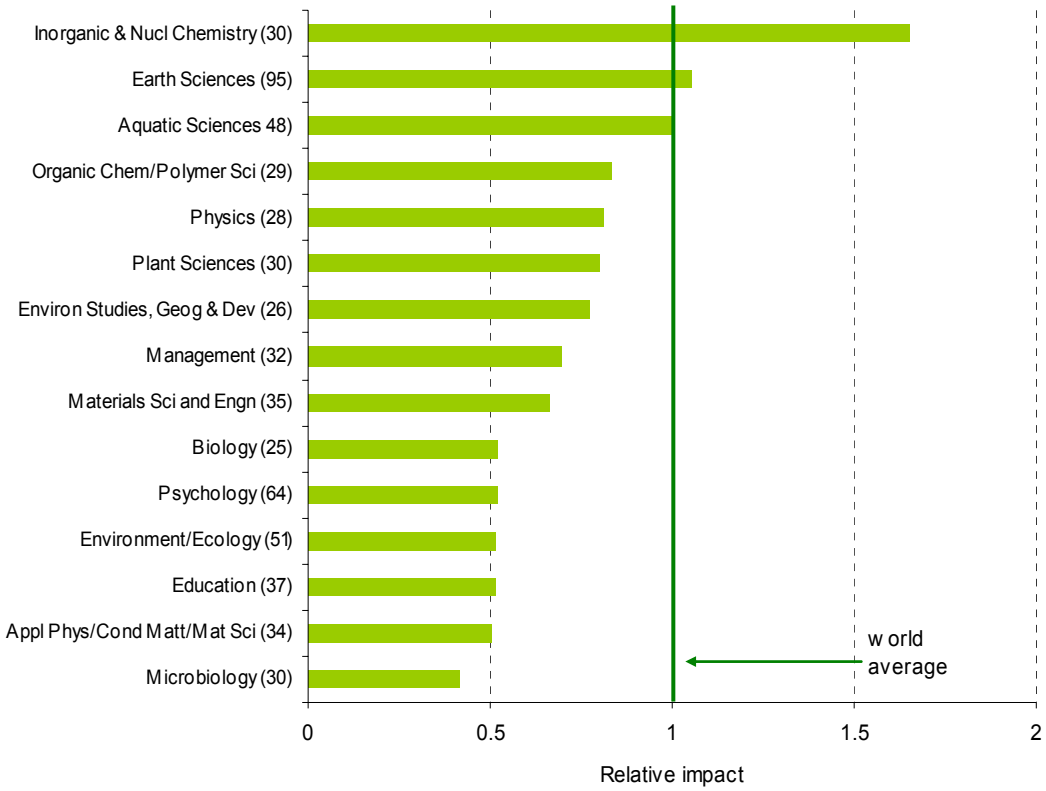
Source: Thomson Scientific

6.2.7 University of Waikato

The relative impact of research in narrow subject areas at the University of Waikato is presented in Figure 33. The smaller scale of the University of Waikato compared with a number of other universities is reflected in the smaller number of categories with publications with 25 or more publications listed in the Thomson Scientific database. Another factor is that the university does not have a medical school and has a large focus on the social sciences and humanities.

Three of the 15 narrow subject areas featured in Figure 33 had a relative impact above the world average. These are all in the physical sciences area, with 'inorganic and nuclear chemistry' having a particularly high relative impact score of 1.65. The largest number of publications (95) in a narrow subject area at the University of Waikato was in the 'earth sciences', which achieved a relative impact score of 1.05.

Figure 33: Relative impact of research at the University of Waikato by narrow subject area 2001-2005



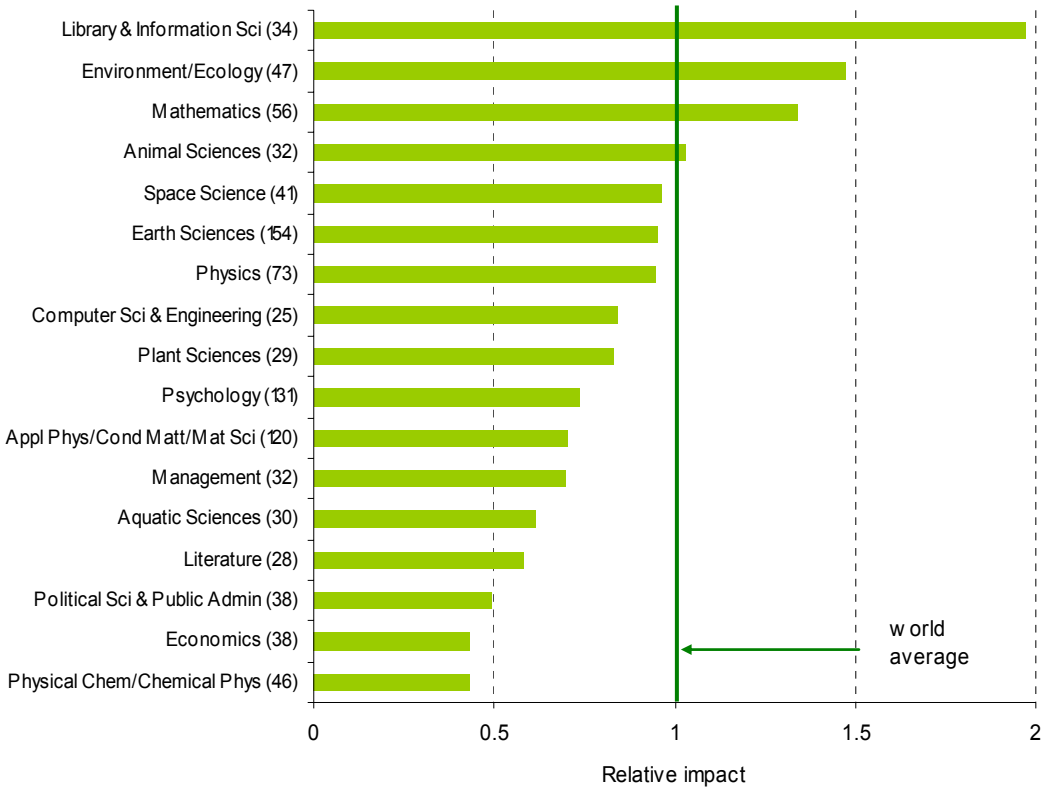
Source: Thomson Scientific

6.2.8 Victoria University of Wellington

Figure 34 presents the relative impact scores of the narrow subject areas at Victoria University of Wellington (VUW). Overall, four of the 17 narrow subject areas at VUW achieved a relative impact score above the world average. Of these, 'library and information sciences' had the highest relative impact score of 1.97. 'Environment/ecology' followed with a relative impact score of 1.48, followed by 'mathematics' with a score of 1.34.

The largest number of publications listed in the Thomson Scientific database at VUW was in the narrow field of 'earth sciences' with 154. The relative impact score of 0.95 in this area was just under the world average.

Figure 34: Relative impact of research at Victoria University of Wellington by narrow subject area 2001-2005



Source: Thomson Scientific

7 Conclusion

The bibliometric data used in this study suggests that in several subject areas the academic impact of New Zealand university research compares favourably with that worldwide. However, it also identifies (as did the PBRF Quality Evaluation in terms of research quality) that the performance of individual universities can vary considerably. As a result of this variation, no one university dominated in all PBRF panels at all times. This variation is to be expected, given the different research focus at the universities and the natural turnover of researchers that occurs over time.

The analysis of the relative impact of research at the narrow subject level showed that New Zealand universities exhibited strong research performance in several areas in the period 2001-2005. In many cases this strong performance was in the specialist areas of the universities.

Although there were a number of areas where universities exhibited research impact that was well above the world average, the fact that several universities exhibited research impact below the world average needs to be placed in context and should not be seen as necessarily indicating a low level of research performance. An analysis of the performance of United Kingdom institutions using a similarly constructed relative impact measure, found that only around a quarter of institutions in most subject areas achieved scores above the world average (Adams and Smith, 2006). Also, the research performance of an institution needs to be carefully considered across a variety of measures so that a more balanced picture of performance can be ascertained.

Although the time period used in this study does not allow an analysis of whether the introduction of performance-based funding has resulted in an increase in the impact of research, overseas studies of the impact of peer assessment have identified an increase in citation rate following the change in funding system. For example, Adams and Smith (2006) found that the rate of citation increased in the United Kingdom following the introduction of the Research Assessment Exercise in 1986. In particular, the authors found that the relative impact of research by institutions that had been rated as high quality in the Research Assessment Exercise increased relative to institutions that were rated at lower levels of quality. As the bibliometric datasets used in this report can be updated on an annual basis, future monitoring of citations may help to identify if similar patterns develop in New Zealand.

Appendix A: Data tables

Table 1: Relative impact of New Zealand university research by narrow subject area 2001-2005

Narrow subject area	Relative impact	Narrow subject area	Relative impact
Geol/petrol/mining engn (32)	2.60	Medical res, diag & treatmt (180)	0.92
Language & linguistics (71)	1.82	Medical res, general topics (470)	0.91
Optics & acoustics (132)	1.75	Physics (330)	0.90
Entomology/pest control (73)	1.69	Engineering mgmt/general (139)	0.90
Library & information sci (62)	1.53	Biochemistry & biophysics (358)	0.90
Cardiovasc & respirat syst (210)	1.47	Environ studies, geog & dev (182)	0.90
Pediatrics (241)	1.44	Appl phys/cond matt/mat sci (512)	0.89
Archaeology (41)	1.42	Molecular biology & genetics (233)	0.89
Reproductive medicine (202)	1.42	Oncogenesis & cancer res (150)	0.88
Chemistry (215)	1.41	Endocrinol, nutrit & metab (333)	0.88
Rehabilitation (56)	1.33	Clin immunol & infect dis (86)	0.87
Chemical engineering (128)	1.31	Materials sci and engn (243)	0.87
Medical res, organs & syst (440)	1.28	Anesthesia & intensive care (87)	0.86
Food science/nutrition (341)	1.27	Psychology (844)	0.86
Rheumatology (56)	1.27	Resrch/lab med & med techn (124)	0.84
Ortho, rehab & sports med (129)	1.26	Philosophy (72)	0.82
Inorganic & nucl chemistry (204)	1.26	Organic chem/polymer sci (317)	0.82
Mechanical engineering (128)	1.24	Biotechnol & appl microbiol (104)	0.82
Gastroenterol and Hepatology (52)	1.24	Microbiology (406)	0.80
Social work & social policy (48)	1.22	Pharmacology & toxicology (325)	0.79
Ai, robotics & auto control (119)	1.18	Endocrinol, metab & nutrit (217)	0.75
Psychiatry (227)	1.16	Surgery (100)	0.74
Mathematics (388)	1.15	Education (187)	0.74
Environment/ecology (834)	1.15	Agricultural chemistry (120)	0.74
Agriculture/agronomy (305)	1.15	Neurosciences & behavior (683)	0.73
Civil engineering (160)	1.14	Phys chem/chemical phys (364)	0.73
Veterinary med/animal health (364)	1.13	Multidisciplinary (352)	0.73
Oncology (109)	1.12	Environmt engineering/energy (99)	0.73
Aquatic sciences (539)	1.10	Economics (301)	0.72
History (101)	1.10	Computer sci & engineering (147)	0.70
Environmt med & public hlth (169)	1.08	Spectrosc/instrum/analyt sci (104)	0.70
Sociology & social sciences (109)	1.07	Plant sciences (555)	0.68
Pharmacology/toxicology (103)	1.06	Chemistry & analysis (366)	0.67
Animal sciences (539)	1.03	Animal & plant sciences (177)	0.67
Biology (332)	1.02	Physiology (162)	0.65
Dentistry/oral surgery & med (88)	1.01	Instrumentation/measurement (51)	0.65
Public hlth & hlth care sci (423)	1.01	Management (182)	0.63
Info technol & commun syst (105)	1.01	Immunology (147)	0.63
Urology (66)	0.99	Literature (134)	0.62
Engineering mathematics (112)	0.99	Hematology (45)	0.56
Clin psychology & psychiatry (225)	0.98	Radiol, nucl med & imaging (46)	0.55
Ophthalmology (134)	0.97	Political sci & public admin (152)	0.53
Space science (175)	0.96	Anthropology (80)	0.52
Otolaryngology (33)	0.95	Cell & developmental biol (120)	0.50
Health care sci & services (95)	0.95	Elect & electronic engn (157)	0.48
Experimental biology (181)	0.94	Communication (72)	0.47
Neurology (150)	0.93	Performing arts (33)	0.29
Earth sciences (875)	0.92		
Cardiovasc & hematology res (188)	0.92		
General & internal medicine (433)	0.92		

Note: The number in brackets after the narrow subject field is the number of publications listed in the Thomson Scientific database in the 2001-2005 period.
Source: Thomson Scientific

Table 2: Relative impact of research at Auckland University of Technology by narrow subject area 2001-2005

Narrow subject area	Relative impact
Ortho, rehab & sports med (29)	0.90

Note: The number in brackets after the narrow subject field is the number of publications listed in the Thomson Scientific database in the 2001-2005 period.
Source: Thomson Scientific

Table 3: Relative impact of research at Lincoln University by narrow subject area 2001-2005

Narrow subject area	Relative impact
Agriculture/agronomy (112)	1.26
Animal sciences (50)	1.26
Environment/ecology (149)	1.16
Veterinary med/animal health (26)	0.95
Food science/nutrition (25)	0.91
Plant sciences (61)	0.72

Note: The number in brackets after the narrow subject field is the number of publications listed in the Thomson Scientific database in the 2001-2005 period.
Source: Thomson Scientific

Table 4: Relative impact of research at Massey University by narrow subject area 2001-2005

Narrow subject area	Relative impact	Narrow subject area	Relative impact
Food science/nutrition (140)	1.38	Molecular biology & genetics (34)	0.72
Experimental biology (33)	1.25	Organic chem/polymer sci (33)	0.71
Biology (69)	1.21	Microbiology (93)	0.70
Veterinary med/animal health (285)	1.18	Plant sciences (106)	0.68
Agriculture/agronomy (133)	1.11	Biochemistry & biophysics (57)	0.68
Engineering mgmt/general (27)	1.08	Physical chem/chemical phys (51)	0.64
Biotechnol & appl microbiol (47)	0.95	Physics (32)	0.61
Environmt med & public hlth (30)	0.94	Earth sciences (50)	0.59
Inorganic & nucl chemistry (27)	0.92	Education (38)	0.58
Mathematics (49)	0.91	Multidisciplinary (34)	0.54
Environment/ecology (144)	0.91	Animal & plant sciences (49)	0.53
Management (27)	0.90	Psychology (112)	0.42
Animal sciences (148)	0.88	Chemistry & analysis (53)	0.41
Endocrinol, nutrit & metab (42)	0.76	Economics (51)	0.36
Environ studies, geog & dev (25)	0.74	Medical res, general topics (34)	0.36
Appl phys/cond matt/mat sci (37)	0.73	Agricultural chemistry (41)	0.34
Public hlth & hlth care sci (63)	0.73	Elect & electronic engn (25)	0.34
Aquatic sciences (27)	0.72		

Note: The number in brackets after the narrow subject field is the number of publications listed in the Thomson Scientific database in the 2001-2005 period.
Source: Thomson Scientific

Table 5: Relative impact of research at the University of Auckland by narrow subject area 2001-2005

Narrow subject area	Relative impact	Narrow subject area	Relative impact
Optics & acoustics (51)	2.70	Pharmacology & toxicology (120)	0.98
Rheumatology (28)	2.01	Endocrinol, nutrit & metab (122)	0.94
Mechanical engineering (77)	1.75	Public hlth & hlth care sci (118)	0.93
Environment/ecology (118)	1.69	Medical res, diag & treatmt (51)	0.92
Reproductive medicine (95)	1.52	Computer sci & engineering (62)	0.91
Chemistry (70)	1.50	Chemistry & analysis (145)	0.91
Education (47)	1.46	Biology (58)	0.89
Pharmacology/toxicology (32)	1.44	Anesthesia & intensive care (42)	0.87
Environ studies, geog & dev (48)	1.44	Psychiatry (72)	0.86
Philosophy (28)	1.39	Biochemistry & biophysics (109)	0.85
Chemical engineering (60)	1.37	Engineering mathematics (34)	0.85
Ortho, rehab & sports med (39)	1.31	Psychology (194)	0.84
Medical res, organs & syst (187)	1.29	Literature (51)	0.83
Cardiovasc & respirat syst (72)	1.28	Environmt engineering/energy (35)	0.83
Pediatrics (87)	1.26	Earth sciences (218)	0.83
Environmt med & public hlth 46)	1.26	Experimental biology (46)	0.82
General & internal medicine (150)	1.24	Clin psychology & psychiatry (67)	0.82
Food science/nutrition (56)	1.23	Plant sciences (106)	0.79
Mathematics (166)	1.23	Oncogenesis & cancer res (67)	0.78
Appl phys/cond matt/mat sci (144)	1.18	Organic chem/polymer sci (108)	0.76
Aquatic sciences (117)	1.18	Materials sci and engn (110)	0.76
Physics (102)	1.17	Health care sci & services (31)	0.76
Medical res, general topics (166)	1.17	Neurosciences & behavior (259)	0.76
Ophthalmology (86)	1.13	Surgery (42)	0.76
Animal sciences (58)	1.12	Endocrinol, metab & nutrit (82)	0.76
Neurology (64)	1.11	Microbiology (61)	0.71
Molecular biology & genetics (94)	1.08	Anthropology (39)	0.64
Economics (100)	1.07	Management (47)	0.61
Cardiovasc & hematology res (77)	1.07	Cell & developmental biol (51)	0.59
Civil engineering (60)	1.03	Spectrosc/instrum/analyt sci (27)	0.51
Inorganic & nucl chemistry (45)	1.03	Immunology (31)	0.51
Phys chem/chemical phys (102)	1.01	Resrch/lab med & med techn (45)	0.49
Animal & plant sciences (39)	1.00	Political sci & public admin (40)	0.38
Multidisciplinary (104)	1.00	History (29)	0.38
Oncology (48)	1.00	Engineering mgmt/general (40)	0.38
Ai, robotics & auto control (37)	0.99	Elect & electronic engn (32)	0.22
Physiology (73)	0.99		

Note: The number in brackets after the narrow subject field is the number of publications listed in the Thomson Scientific database in the 2001-2005 period.
Source: Thomson Scientific

Table 6: Relative impact of research at the University of Otago by narrow subject area 2001-2005

Narrow subject area	Relative impact	Narrow subject area	Relative impact
Pediatrics (141)	1.60	Neurology (64)	0.88
Inorganic & nucl chemistry (52)	1.60	Chemistry (35)	0.87
Ortho, rehab & sports med (47)	1.51	Medical res, general topics (238)	0.86
Cardiovasc & respirat syst (130)	1.48	Gastroenterol and hepatology (31)	0.86
Food Science/nutrition (80)	1.41	Spectrosc/instrum/analyt sci (28)	0.85
Veterinary med/animal health (25)	1.39	Molecular biology & genetics (77)	0.83
Aquatic sciences (222)	1.38	Cardiovasc & hematology res (102)	0.83
Optics & acoustics (30)	1.38	Endocrinol, nutrit & metab (152)	0.83
Reproductive medicine (92)	1.35	Appl phys/cond matt/mat sci (43)	0.82
Psychology (212)	1.35	Physical chem/chemical phys (69)	0.81
Resrch/lab med & med techn (57)	1.33	Endocrinol, metab & nutrit (115)	0.79
Psychiatry (134)	1.31	Physics (43)	0.78
Public hlth & hlth care sci (169)	1.29	Neurosciences & behavior (316)	0.77
Medical res, organs & syst (208)	1.27	Anesthesia & intensive care (39)	0.77
Earth sciences (196)	1.24	General & internal medicine (251)	0.76
Oncology (57)	1.19	Organic chem/polymer sci (29)	0.75
Animal sciences (155)	1.16	Ophthalmology (43)	0.75
Biochemistry & biophysics (133)	1.14	Pharmacology & toxicology (150)	0.74
Clin psychology & psychiatry (139)	1.12	Surgery (54)	0.74
Health care sci & services (47)	1.11	Immunology (84)	0.70
Biology (117)	1.06	Multidisciplinary (99)	0.67
Dentistry/oral surgery & med (84)	1.06	Chemistry & analysis (68)	0.62
Environmt med & public hlth (84)	1.04	Plant sciences (93)	0.58
Pharmacology/toxicology (59)	1.03	Cell & developmental biol (40)	0.54
Urology (57)	1.01	Environ studies, geog & dev (37)	0.48
Microbiology (183)	1.01	Animal & plant sciences (46)	0.46
Experimental biology (60)	0.97	Economics (33)	0.45
Oncogenesis & cancer res (75)	0.95	Physiology (37)	0.44
Medical res, diag & treatmt (120)	0.94	Management (25)	0.42
Clin immunol & infect dis (57)	0.93	Hematology (32)	0.41
Environment/ecology (181)	0.91		

Note: The number in brackets after the narrow subject field is the number of publications listed in the Thomson Scientific database in the 2001-2005 period.
Source: Thomson Scientific

Table 7: Relative impact of research at the University of Canterbury by narrow subject area 2001-2005

Narrow subject area	Relative impact	Narrow subject area	Relative impact
Chemical engineering (35)	2.05	Aquatic sciences (77)	0.74
Engineering mgmt/general (34)	1.75	Psychology (119)	0.72
Environment/ecology (137)	1.40	Materials sci and engn (49)	0.69
Engineering mathematics (36)	1.39	Physics (51)	0.67
Info technol & commun Syst (56)	1.21	Earth sciences (141)	0.63
Chemistry (58)	1.20	Physical chem/chemical phys (78)	0.61
Inorganic & nucl chemistry (41)	1.17	Political sci & public admin (28)	0.61
Optics & acoustics (34)	1.16	Plant sciences (128)	0.58
Mathematics (73)	1.16	Biology (40)	0.58
Space science (71)	1.15	Chemistry & analysis (65)	0.58
Civil engineering (71)	1.12	Mechanical engineering (25)	0.57
Literature (25)	1.00	Elect & electronic engn (78)	0.54
Economics (32)	0.98	Public hlth & hlth care sci (25)	0.53
Appl phys/cond matt/mat sci (125)	0.98	Multidisciplinary (67)	0.51
Organic chem/polymer sci (96)	0.97	Neurosciences & behavior (52)	0.46
History (28)	0.86	Microbiology (30)	0.41
Animal sciences (71)	0.85	Education (25)	0.23

Note: The number in brackets after the narrow subject field is the number of publications listed in the Thomson Scientific database in the 2001-2005 period.
Source: Thomson Scientific

Table 8: Relative impact of research at the University of Waikato by narrow subject area 2001-2005

Narrow subject area	Relative impact	Narrow subject area	Relative impact
Inorganic & nucl chemistry (30)	1.65	Materials sci and engn (35)	0.66
Earth sciences (95)	1.05	Biology (25)	0.52
Aquatic sciences 48)	1.00	Psychology (64)	0.52
Organic chem/polymer sci (29)	0.84	Environment/ecology (51)	0.52
Physics (28)	0.81	Education (37)	0.51
Plant sciences (30)	0.80	Appl phys/cond matt/mat Sci (34)	0.51
Environ studies, geog & dev (26)	0.78	Microbiology (30)	0.42
Management (32)	0.70		

Note: The number in brackets after the narrow subject field is the number of publications listed in the Thomson Scientific database in the 2001-2005 period.
Source: Thomson Scientific

Table 9: Relative impact of research at Victoria University of Wellington by narrow subject area 2001-2005

Narrow subject area	Relative impact	Narrow subject area	Relative impact
Physical chem/chemical phys (46)	0.43	Computer sci & engineering (25)	0.84
Economics (38)	0.43	Physics (73)	0.95
Political sci & public admin (38)	0.50	Earth sciences (154)	0.95
Literature (28)	0.58	Space science (41)	0.96
Aquatic sciences (30)	0.61	Animal sciences (32)	1.03
Management (32)	0.70	Mathematics (56)	1.34
Appl phys/cond matt/mat sci (120)	0.70	Environment/ecology (47)	1.48
Psychology (131)	0.73	Library & information sci (34)	1.97
Plant sciences (29)	0.83		

Note: The number in brackets after the narrow subject field is the number of publications listed in the Thomson Scientific database in the 2001-2005 period.
Source: Thomson Scientific

Appendix B: Mapping of PBRF panels to Thomson Scientific subject areas

PBRF subject panels	Thomson Scientific subject fields
Biological sciences	Agriculture/agronomy
	Agricultural chemistry
	Animal & plant sciences
	Animal sciences
	Aquatic sciences
	Biochemistry & biophysics
	Biology
	Biotechnology & applied microbiology
	Cell & developmental biology
	Endocrinology, nutrition & metabolism
	Entomology/pest control
	Environment/ecology
	Experimental biology
	Food science/nutrition
	Immunology
	Microbiology
	Molecular biology & genetics
	Neurosciences & behaviour
	Physiology
	Plant sciences
Business and economics	Economics
	Management
Education	Education
Engineering, technology and architecture	Aerospace engineering
	AI, robotics & automatic control
	Art & architecture
	Civil engineering
	Electrical & electronics engineering
	Engineering management/general
	Engineering mathematics
	Environmental engineering & energy
	Instrumentation & measurement
	Mechanical engineering
	Nuclear engineering
Health	Dentistry/oral surgery & medicine
	Orthopaedics, rehabilitation & sports medicine
	Rehabilitation
	Veterinary medicine/animal health
Humanities and law	Classical studies
	History
	Language & linguistics
	Law
	Literature
	Philosophy
	Religion & theology

PBRF subject panels	Thomson Scientific subject fields
Mathematical and information sciences and technology	Computer science & engineering Information technology & communications systems Library & information sciences Mathematics
Medicine and public health	Anaesthesia & intensive care Cardiovascular & haematology research Cardiovascular & respiratory systems Clinical immunology & infectious disease Clinical psychology & psychiatry Dermatology Endocrinology, metabolism & nutrition Environmental medicine & public health Gastroenterology & hepatology General & internal medicine Health care sciences & services Hematology Medical research, diagnosis & treatment Medical research, general topics Medical research, organs & systems Neurology Oncogenesis & cancer research Oncology Ophthalmology Otolaryngology Paediatrics Pharmacology & toxology Pharmacology/toxicology Psychiatry Public health & health care science Radiology, nuclear medicine & imaging Reproductive medicine Research/laboratory medicine & medical technology Rheumatology Surgery Urology
Physical sciences	Applied physics/condensed matter/materials science Chemical engineering Chemistry Chemistry & analysis Earth sciences Geological, petroleum & mining engineering Inorganic & nuclear chemistry Materials science & engineering Metallurgy Optics & acoustics Organic chemistry/polymer science Physical chemistry/chemical physics Physics Space science Spectroscopy/instrumentation/analytical sciences

PBRF subject panels	Thomson Scientific subject fields
Social sciences and other cultural/social studies	Anthropology
	Archaeology
	Communication
	Environmental studies, geography & development
	Political science & public administration
	Psychology
	Social work & social policy
	Sociology & social sciences

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