MINISTRY OF EDUCATION
Te Tāhuhu o te Mātauranga

Quality vs impact

A comparison of Performance-Based Research Fund quality scores with citations

Research and knowledge creation

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

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1 Summary

This report is the second in a series that uses a newly available bibliometrics dataset from Thomson Scientific to analyse the research performance of New Zealand universities. The first report in this series – *(ex)Citing research* – examined the academic impact of research by New Zealand universities over a period of 25 years between 1981 and 2005. This new report compares the academic impact of research produced by New Zealand universities, in the form of citations per full-time equivalent researcher, with the quality of research at the universities, as measured by Performance-Based Research Fund (PBRF) average quality scores, across 10 broad subject areas. In doing so, this report contributes to the evaluation of the PBRF.

The dataset used in this report – the Thomson Scientific De-luxe dataset - draws on research published in around 10,000 journals. The dataset has better coverage of research in some subject areas than others; for example, the biological and medical sciences have the best coverage. Subject areas such as business, the social sciences and humanities have a lesser degree of coverage. Also, because of differences in publishing conventions among subject disciplines, the research output of some subjects is better represented in the Thomson Scientific dataset than others. For example, in subject disciplines such as the social sciences – where books and book chapters are important means of disseminating new knowledge – large proportions of research output will not be captured in this analysis. Also, research that is published in local journals is generally outside of the coverage of the Thomson Scientific dataset. Therefore, research that is of high impact in the New Zealand context may go uncaptured by the dataset used in this report. The first report in this series – *(ex)Citing research* – has a detailed discussion on the limitations of the dataset.

Each of the 10 broad subject panels analysed in this report exhibits a positive association between the quality of research and the academic impact of research – that is, a higher level of academic quality is associated with a higher level of academic impact. However, the strength of this relationship varies among the subject panels and between 2003 and 2006.

Overall, the 'biological sciences' panel displays the strongest degree of association between research quality and academic impact. Other panels with a reasonable degree of association between academic impact and research quality are 'engineering, technology and architecture', 'education' and 'medicine and public health'. Of the remaining subject panels, the lowest degree of association between academic impact and research quality is in the 'business and economics' panel. Given the coverage of the Thomson Scientific dataset and the nature of the publishing conventions in the various subject panel areas, these results are generally in line with expectations.

The strength of the relationship between academic impact and research quality is generally lower in New Zealand than was found in studies of the Research Assessment Exercise (RAE) in the United Kingdom (Smith and Eysenck, 2002; Norris and Oppenheim, 2003). These studies, which looked at the narrow subject areas of psychology and archaeology, found a high degree of correlation between the quality grades allocated in the RAE and citations. However, limitations in the citations dataset used in this analysis, along with the smaller number of universities in New Zealand, are likely to be contributing factors to this lower level of correlation.

The degree of variation between research quality and academic impact found in this report would suggest that the peer review process used in the PBRF Quality Evaluations is not simply mirroring what is shown in citations data. However, given the limitations of the data used in this analysis, further research, which links citations directly to the researchers in the PBRF Quality Evaluation, would more conclusively indicate the strength of the association between research quality and academic impact.

2 Introduction

This report is the second in a series that uses a newly unified[1] bibliometrics dataset from Thomson Scientific to analyse the research performance of New Zealand universities. The first report in this series – *(ex)Citing research* – examined the academic impact of research by New Zealand universities over a period of 25 years between 1981 and 2005. This new report compares the academic impact of research produced by New Zealand universities, in the form of citations per full-time equivalent (FTE) researcher, with the quality of research at the universities, as measured by Performance-Based Research Fund (PBRF) average quality scores, across 10 broad subject areas. In doing so, this report contributes to the evaluation of the PBRF.

A number of studies in the United Kingdom have compared the quality scores allocated to departments by the Research Assessment Exercise (RAE) with the citations attracted by the staff in those departments. Smith and Eysenck (2002) and Norris and Oppenheim (2003) analysed the performance of staff in the 2001 RAE in the areas of psychology and archaeology, respectively. These studies found a high degree of correlation[2] between citation counts and the grade assigned to a department in the RAE. An analysis of the relationship between peer-assessed measures of quality and citations in a New Zealand context will help identify if the PBRF quality measure is capturing something different from that measured by citations.

This report is timely given recent developments in the measurement of research quality overseas. The guidelines for the upcoming Research Quality Framework (RQF) in Australia include the proposed use of metrics (where appropriate), including citations, to assist panel reviewers in their assessment of research quality.[3] It is made clear that the use of metrics is to help inform peer reviewers and not to replace their judgement. In the United Kingdom, the government is considering going even further and replacing peer assessment as the principal measure of research quality with a system of metrics, including citations, to fund research in higher education.

This report has the following structure. The dataset used in the report, the methodology followed and the caveats that apply to the results are discussed in section 3. In section 4, the quality of university research is compared with the academic impact of research across 10 PBRF broad subject panels. Finally, some conclusions are presented in section 5.

1 This is where the publication has been allocated to an institution.
2 These studies used Pearson's correlation coefficient to measure the degree of association.
3 See Research Quality Framework Development Advisory Group (2006) page 18.

3 Data, method and limitations

3.1 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 Thomson Scientific dataset 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 that potentially has the greatest impact in the various fields.

The types of research publications included in the dataset 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 were 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.[4] For example, where researchers may only have referred to a school of medicine as the institution, they 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. As a result, the PBRF average quality scores used in this study have been constructed using the same assumptions.

For the purposes of this study, the 106 narrow subject areas in the Thomson Scientific dataset have been aggregated into 10 broad subject areas. These broad subject areas have been aligned with 10 of the 12 PBRF broad subject panels. The two PBRF panels omitted from this study are 'Māori knowledge and development' and 'creative and performing arts'. The former was omitted because it is impossible to assign publications to this subject area given the structure of the Thomson Scientific dataset, while the latter was omitted due to an insufficient number of publications.[5] The mapping used to allocate the Thomson Scientific narrow subject areas to the PBRF subject panels is presented in Appendix B.

3.2 Method

In this report, the number of citations per PBRF-eligible staff member is used to measure the academic impact of university research. The citations selected in this analysis are from a similar assessment window to that used in the 2003 and 2006 Quality Evaluations. For the comparison with the results of the 2003 Quality Evaluation, the citations associated with publications listed in the Thomson Scientific dataset between 1998 and 2002 have been used. This compares with an assessment window of research outputs between 1997 and 2002 in the 2003 PBRF Quality Evaluation. For the comparison with results from the 2006 Quality Evaluation, citations that were associated with publications listed in the Thomson Scientific dataset between 2001 and 2005 have

4 The Ministry of Education has worked closely with Thomson Scientific to ensure that the research publications have been accurately assigned to the appropriate university.
5 This is not surprising given the nature of this subject area, where publication in academic journals is not likely to be the main way of disseminating newly created knowledge.

been used. This compares with an assessment window of 2000 to 2005 for research outputs in the 2006 Quality Evaluation.

As a result of 'citation inflation' – where rates of citation are naturally rising over time – it is not possible to compare the raw citations per FTE in 2003 and 2006 to ascertain if there has been an increase in the academic impact of research. Therefore, an adjustment to the citations data is required that removes this natural rate of increase. To achieve this, the actual citations in the period 1998-2002 in each PBRF subject panel area and at each university have been multiplied by the percentage increase in worldwide citations between 1998-2002 and 2001-2005 in each panel. This discounts for the impact of 'citation inflation'. However, as this measure is artificially generated, caution should be used when comparing the citations per FTE in 2003 and 2006.

Two measures of association are used in this report to assist in quantifying the relationship between research quality and the academic impact of research. Pearson's correlation coefficient is used to measure the degree of linear association between the two measures. The closer the absolute value of the Pearson's correlation coefficient is to one, the stronger is the linear association between the two measures. A value of one indicates that there is a perfect linear relationship between the two measures – a value of zero indicates there is no linear association between the two measures. The sign of the correlation coefficient indicates whether there is a positive or negative linear relationship between the measures. It is expected that the Pearson correlation coefficients should have a positive sign – a higher level of research quality should be associated with a higher level of academic impact.

The second measure of association used in this report is Spearman's rank order coefficient. This is a non-parametric measure of association that compares the ranking of the universities using the research quality measure with the ranking of the universities using the academic impact measure and indicates the strength of that relationship. A value close to one indicates that the two measures provide a similar ranking of universities. A measure close to zero indicates that the ranking of the universities is very different in terms of research quality and academic impact. As with the Pearson's correlation coefficient, the sign indicates whether the relationship is negative or positive. It is expected that the sign of the Spearman's coefficients will be positive, indicating that a university ranked highly under one measure should be ranked highly under the other.

Both the Pearson's correlation coefficient and the Spearman's rank order coefficient can be tested for statistical significance. Table 1 in Appendix A presents the Pearson's and Spearman's coefficients for each PBRF panel and indicates if they were statistically significant at the five percent level.[6] However, the small number of observations, especially in single time periods, means that the degree of association has to be high to become statistically significant.

Both these measures of association are vulnerable to the influence of outliers – where one pair of observations is well away from the remainder of the dataset. If the university is a relatively small producer of research then this can cause distortions. Also, if the data has a non-linear relationship then the Pearson's correlation coefficient will not reflect this. For these reasons, these measures of association should be used in conjunction with a careful visual inspection of the data.

3.3 Limitations

It is expected that the degree of correlation between quality and academic impact will be lower than that found in the Smith and Eysenck (2002) and Norris and Oppenheim (2003) studies.[7] There are several reasons for this. Firstly, the United Kingdom studies linked citations to the research of individual authors in the departments. The nature of the citations dataset used in this Ministry of

6 This indicates that the association between the two measures has reached a level where we are 95 percent confident that an association exists.
7 These studies had correlation coefficients of over 0.9.

Education report does not allow this linking of citations to the actual researchers assessed in the PBRF. Rather, citations are allocated by the subject area of the journal in which the item was published. This will diminish the degree of correlation between the quality and impact measures. Also, the RAE has been in place since 1986. One of the perceptions in the United Kingdom is that you need to publish in highly cited journals in order to obtain a high RAE rating (Elkin, 2001). If academics in the United Kingdom have behaved accordingly, the RAE scores and citations data will have naturally come into some alignment.

Secondly, publications listed in the Thomson Scientific dataset in the earlier part of the five-year citation window will have a greater impact as they have had a longer time to attract citations. Also, as five years is the maximum time citations are collated for any single publication, this will not capture the impact of seminal research, which may see an increasing rate of citation well beyond the five-year limit.

Thirdly, this study uses subject panels as opposed to narrow subject areas, meaning there is a higher degree of aggregation. Therefore, the degree of correlation that might exist could be diminished. Also, the number of universities in this Ministry of Education study (a maximum of eight in each year) is much smaller than the number used in the Smith and Eysenck (38) and Norris and Oppenheim (58) studies. As indicated in the previous section, a smaller number of observations makes it harder to draw any definitive conclusions about the strength of the relationship between academic impact and research quality.

A further issue that may reduce the degree of correlation relates to the capped nature of the PBRF quality score. The highest score an individual researcher can receive in the PBRF Quality Evaluation is 10. However, there is no artificial limit on citations a researcher's publications may receive. If there is a subject area where the publications of one or two researchers have attracted many citations, but the remainder of the staff in that area have not, a university could receive a relatively high citation per FTE score which may not be reflected necessarily in a high PBRF average quality score.

Another reason for a possible low degree of correlation relates to the construction of the PBRF average quality score. The method of assigning quality scores to a researcher is based on a weighted average of the quality of their research outputs (70 percent), the esteem in which the researcher is held by their peers (15 percent) and the contribution they make to the research environment (15 percent). Although there is likely to be a link between citations and the quality of research output and peer esteem components, this is not likely to be the case in the contribution to the research environment measure.

Finally, the 2006 PBRF Quality Evaluation was a partial round. This meant that staff who participated in both the 2003 and 2006 Quality Evaluations did not have to resubmit their evidence portfolios. Therefore, for those staff who did not resubmit, the score assigned to them in the 2003 Quality Evaluation has been rolled over to 2006. As a result, there is the possibility that the quality of their research may have varied from that indicated in their carried-over score. Hence, the relationship with the number of citations may be reduced.

There are a number of important caveats that apply to the use of citation data. For example, the Thomson Scientific dataset used in this report captures publications in around 10,000 journals, mainly published in North America and Europe. Therefore, this data does not capture research that may have been produced in books, book chapters, articles in journals outside of the coverage of the Thomson Scientific dataset, exhibitions and performances. A more detailed discussion of the caveats that apply to the use of citations is provided in the first report in this series – *(ex)Citing research*. The reader of this report should note these caveats before interpreting these new findings.

4 Results[8]

In this section, the academic impact of research (in the form of citations per FTE PBRF-eligible staff member) is compared with the quality of research (in the form of PBRF average quality score) achieved by a university in 10 broad subject fields. Firstly, an overview of the results across the 10 PBRF panels in 2003 and 2006 is presented. Then, for each of the 10 PBRF broad panel areas, the data is examined individually.

4.1 Overview

All of the 10 panels observed in this study exhibit a positive association between the quality of research and the academic impact of research. However, the strength of this relationship varies among the 10 PBRF subject panels and between 2003 and 2006. Overall, the 'biological sciences' panel displays the strongest degree of association between research quality and academic impact. Other panels with a reasonable degree of association between academic impact and research quality are 'engineering, technology and architecture', 'education' and 'medicine and public health'. Of the remaining subject panels, the lowest degree of association between academic impact and research quality is in the 'business and economics' panel.

Given the nature of the coverage of the Thomson Scientific dataset – which covers the biological sciences and medical sciences well – and the nature of publishing conventions in these fields, the result in the 'biological sciences' and 'medicine and public health' panels is to be expected. The relatively high degree of association between research quality and academic impact in the 'education' panel is a little surprising, given the coverage of the Thomson Scientific dataset.

Generally, the 2003 data shows a stronger degree of linear correlation than in 2006, as the Pearson's correlation coefficients are higher in seven of the 10 panels in 2003, compared with 2006. Also, there are four panels with a statistically significant correlation in 2003, whereas for 2006 there are none.

The fit of the data changes markedly in some panels between 2003 and 2006. For example the degree of association between research quality and academic impact improves markedly in the 'health' and 'physical sciences' panels, although, in the case of 'physical sciences', this improvement is mainly due to the impact of one outlier lowering the value of the Pearson's correlation coefficient in the 2003 results.

The Pearson correlation coefficients obtained in this analysis of the 10 panels – which ranged from 0.05 to 0.93 - are generally significantly lower than was found in the Smith and Eysenck (2002) and Norris and Oppenheim (2003) studies, which was over 0.9. However, the smaller number of observations and the impact of outliers are factors in the lower degree of association in the New Zealand data.

A more detailed analysis of each of the 10 PBRF subject panels is presented in the sections that follow. Note that for clarity of presentation, the latest data, which aligns with the 2006 Quality Evaluation, is presented in graphical form first. Then the data that aligns with the 2003 and 2006 Quality Evaluations is presented together in the same graph. Also, the university names that appear in the graphs have been abbreviated. The abbreviations are: Auckland University of Technology (AUT), Lincoln University (LN), Massey University (MY), University of Auckland (AK), University of Canterbury (CY), University of Otago (OT), University of Waikato (WK) and Victoria University of Wellington (VUW).

8 Note that the mean values of citations per FTE and PBRF average quality scores are indicated by dotted lines in the graphs in this section. Also, Table 1 in Appendix A displays the Pearson's and Spearman's coefficients.

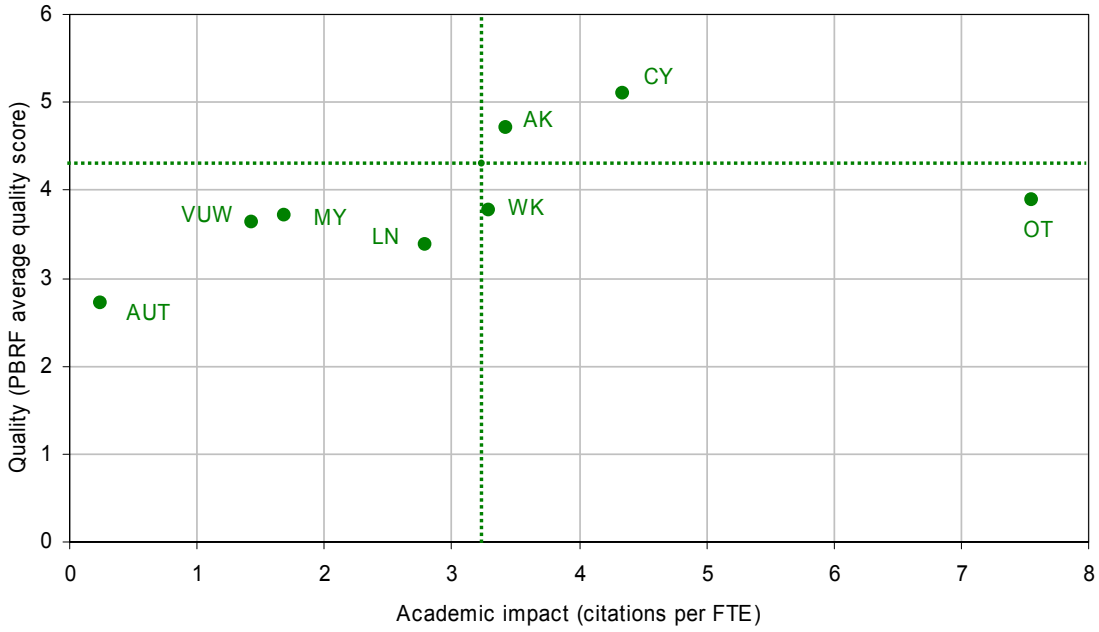
4.2 Engineering, technology and architecture

The academic impact and quality of research for the eight universities in the 'engineering, technology and architecture' panel for 2006 are displayed in Figure 1. As can be seen, there is a reasonable degree of positive linear correlation between quality of research and academic impact for seven of the eight universities with one apparent outlier - the University of Otago.[9] The Pearson's correlation coefficient value of 0.57 is not statistically significant at the five percent level, although this is negatively impacted by the outlier.

The ranking of the universities in academic impact and research quality shows a strong degree of association - the Spearman's rank order coefficient is 0.86 and is statistically significant at the five percent level.

The quality and academic impact of research at two universities, Auckland and Canterbury, are above the university mean in 2006. The fact that these two universities have well-established engineering schools would be a factor in this result.

Figure 1: Academic impact vs quality of research in 'engineering, technology and architecture' by university 2006



Notes:
1. The citations per FTE measure is calculated by dividing the number of citations associated with publications listed in the Thomson Scientific dataset between 2001 and 2005 by the PBRF-eligible FTE in 2006.
2. The dotted lines in the graph illustrate the mean values.
Source: Thomson Scientific and the Tertiary Education Commission

Figure 2 presents the academic impact and quality of research in 2003 (and also 2006). As is the case in 2006, there appears to be a positive linear relationship between academic impact and research quality in this panel with two slight outliers – Victoria University of Wellington and the University of Otago. The 2003 Pearson's correlation coefficient of 0.67 is slightly higher than in 2006. However, the association in the ranking of the universities under the two measures in 2003 is much weaker than in 2006. The Spearman's rank coefficient of 0.48 is not statistically significant at the five percent level.

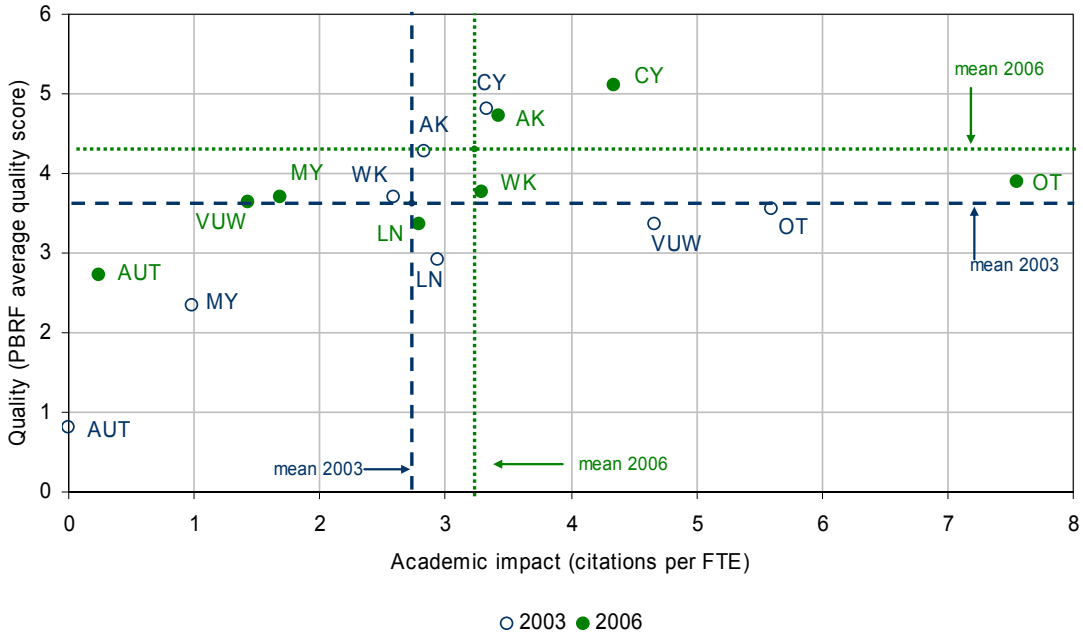
9 This is a result of highly cited articles in the narrow subject area of 'AI, robotics and auto control', which boosted the academic impact of University of Otago research in this subject area.

When combined, the 2003 and 2006 data exhibits a statistically significant Pearson's correlation coefficient and Spearman's rank order coefficient – a result that is assisted by the increased number of observations.

The association between academic impact and quality of research can also be gauged by examining how the respective measures changed between 2003 and 2006. For example, the improvement in the mean academic impact of research by the universities between 2003 and 2006 was matched by an increase in the mean quality of research. At the individual institution level, academic impact and the quality of research changed in the same direction between 2003 and 2006 at six of the eight universities assessed in this panel. This suggests that in this panel at least, the direction of change in one measure is generally mirrored by changes in the other.

The Universities of Auckland and Canterbury are the only universities that achieved above average scores in both academic impact and research quality measures in both 2003 and 2006.

Figure 2: Academic impact vs quality of research in 'engineering, technology and architecture' by university 2003 and 2006



Notes:
1. The citations per FTE measure in 2003 is calculated by dividing the number of citations associated with publications listed in the Thomson Scientific dataset between 1998 and 2002 by the PBRF-eligible FTE in 2003.
2. The citations per FTE measure in 2006 is calculated by dividing the number of citations associated with publications listed in the Thomson Scientific dataset between 2001 and 2005 by the PBRF-eligible FTE in 2006.
3. The citations per FTE measure in 2003 has been adjusted for the effects of citation inflation.
4. The dotted lines in the graph illustrate the mean values.
Source: Thomson Scientific and the Tertiary Education Commission

4.3 Mathematical and information sciences and technology

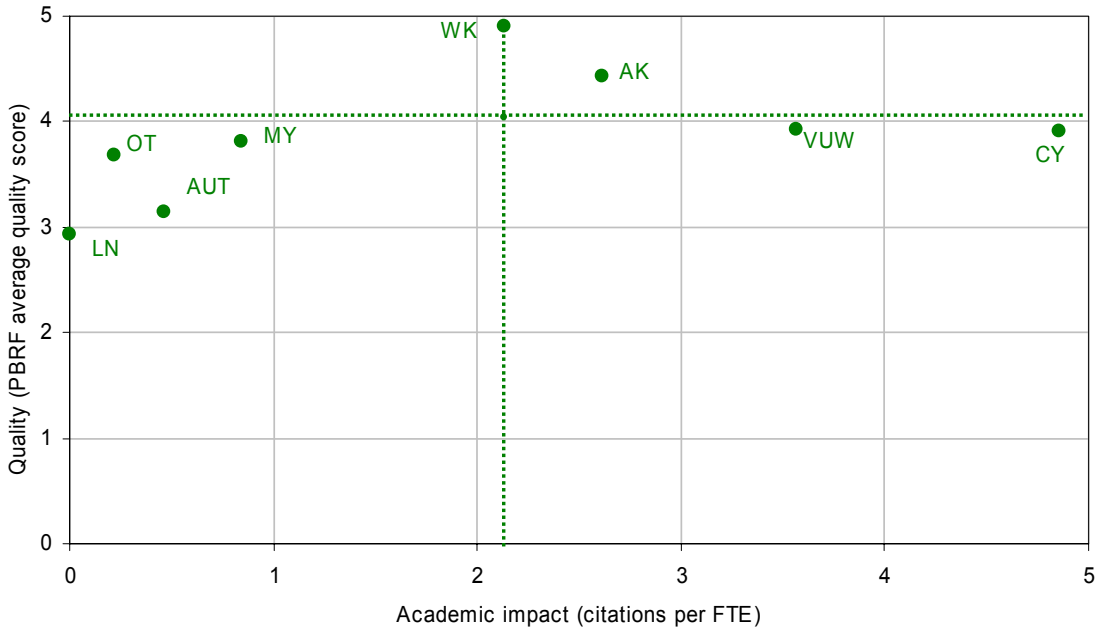
The association between the academic impact and quality of research by the universities in the 'mathematical and information science and technology' panel in 2006 is displayed in Figure 3. Visually, it appears there is a lower degree of linear correlation than in the 'engineering, technology and architecture' panel. Victoria University of Wellington and the University of Canterbury in particular achieved an above average academic impact score that is not reflected in their research quality score. This is reflected in a Pearson's correlation coefficient value of 0.51 which is not statistically significant.

The University of Canterbury's high citations per FTE score is partly due to a high number of citations in the information sciences area. Similarly, Victoria University of Wellington's high citations per FTE score is partly a result of a large number of citations in the narrow subject area of 'library and information sciences'.

The ranking of the universities under the two measures also exhibits a slightly weaker relationship than in the 'engineering, technology and architecture' panel. However, the Spearman's rank order coefficient of 0.74 is still statistically significant.

Research at two universities, Waikato and Auckland, exhibits above average quality and academic impact in 2006.

Figure 3: Academic impact vs quality of research in 'mathematical and information science and technology' by university 2006



Notes:
1. The citations per FTE measure is calculated by dividing the number of citations associated with publications listed in the Thomson Scientific dataset between 2001 and 2005 by the PBRF-eligible FTE in 2006.
2. The dotted lines in the graph illustrate the mean values.
Source: Thomson Scientific and the Tertiary Education Commission

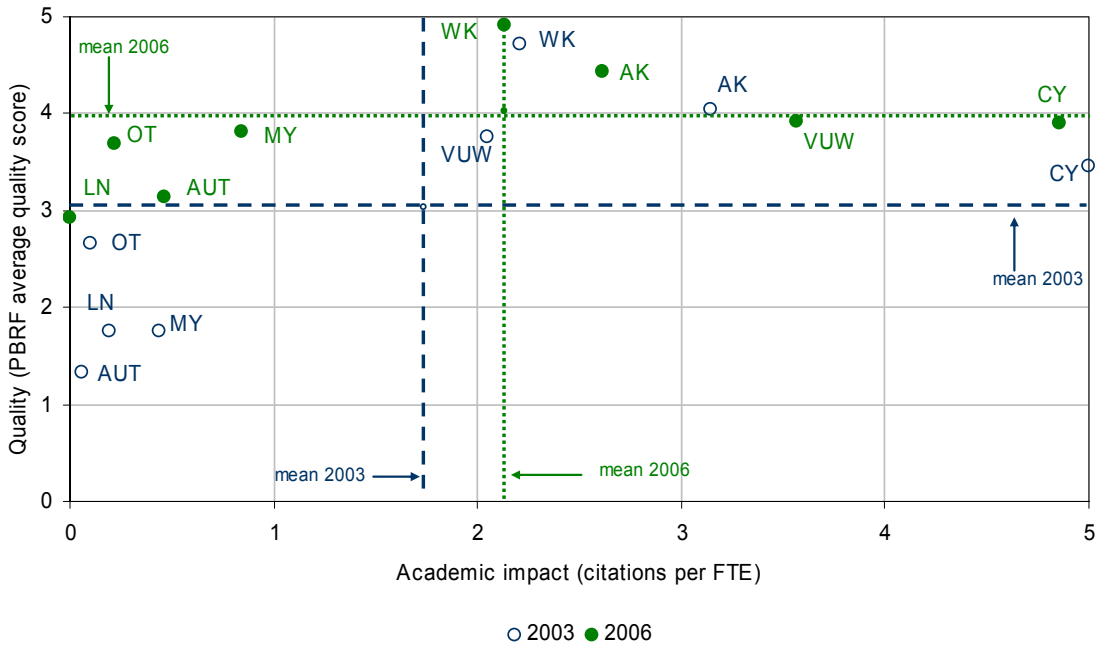
Figure 4 presents the academic impact and quality of research in this panel in 2003. Visually, there appears to be a lower degree of linear correlation between the two measures than in 2006. Although the 2003 data has a stronger numerical association than the 2006 data – exhibited by a higher Pearson's correlation coefficient (0.70) and Spearman's rank order coefficient (0.75) - this is due to the impact of an outlier, the University of Canterbury, biasing the results upwards. When the 2003 and

2006 data is combined, the Pearson's correlation coefficient and Spearman's rank coefficient are both statistically significant.

The mean academic impact and mean quality of research both increased between 2003 and 2006. At the individual university level, four of the eight universities in this panel saw academic impact and research quality move in the same direction.

The Universities of Auckland and Waikato are the only two universities that achieved above average academic impact and research quality in both 2003 and 2006.

Figure 4: Academic impact vs quality of research in 'mathematical and information science and technology' by university 2003 and 2006



Notes:
1. The citations per FTE measure in 2003 is calculated by dividing the number of citations associated with publications listed in the Thomson Scientific dataset between 1998 and 2002 by the PBRF-eligible FTE in 2003.
2. The citations per FTE measure in 2006 is calculated by dividing the number of citations associated with publications listed in the Thomson Scientific dataset between 2001 and 2005 by the PBRF-eligible FTE in 2006.
3. The citations per FTE measure in 2003 has been adjusted for the effects of citation inflation.
4. The dotted lines in the graph illustrate the mean values.
Source: Thomson Scientific and the Tertiary Education Commission

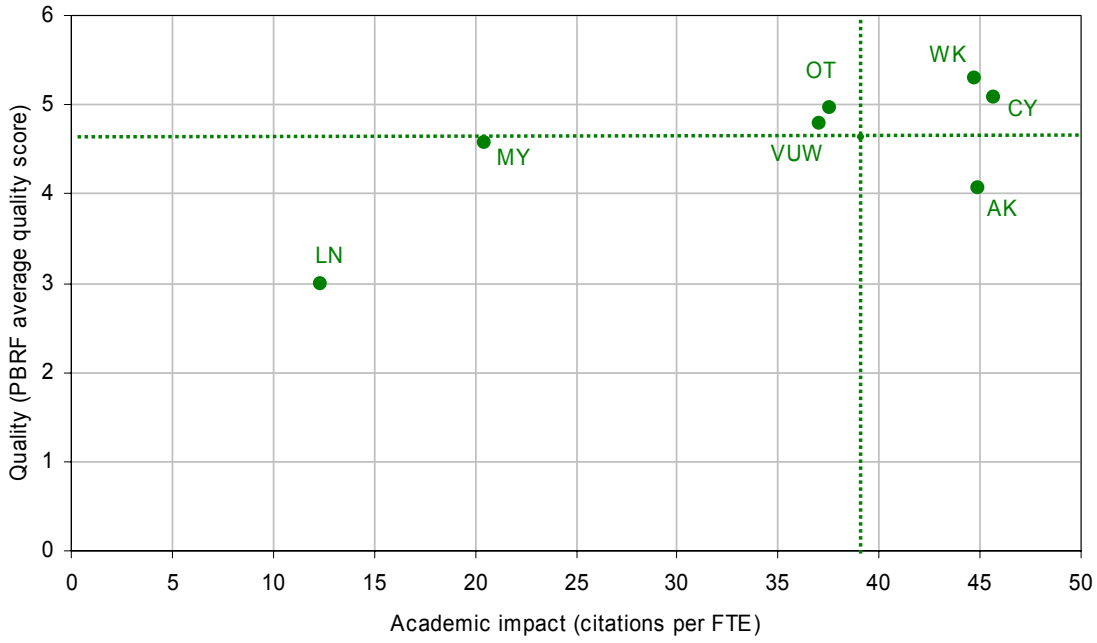
4.4 Physical sciences

The relationship between academic impact of research and the quality of research in the 'physical sciences' panel in 2006 is presented in Figure 5. Visually, there appears to be a reasonable degree of positive linear correlation between academic impact and quality of research, with the University of Auckland being a slight outlier.[10] The Pearson's correlation coefficient has a value of 0.72, but is not statistically significant.

The ranking of the universities under the two measures shows a relatively weak relationship – the Spearman's rank order coefficient of 0.51 is not statistically significant.

The Universities of Waikato and Canterbury achieved above average academic impact and research quality in 2006.

Figure 5: Academic impact vs quality of research in 'physical sciences' by university 2006



Notes:
1. The citations per FTE measure is calculated by dividing the number of citations associated with publications listed in the Thomson Scientific dataset between 2001 and 2005 by the PBRF-eligible FTE in 2006.
2. The dotted lines in the graph illustrate the mean values.
Source: Thomson Scientific and the Tertiary Education Commission

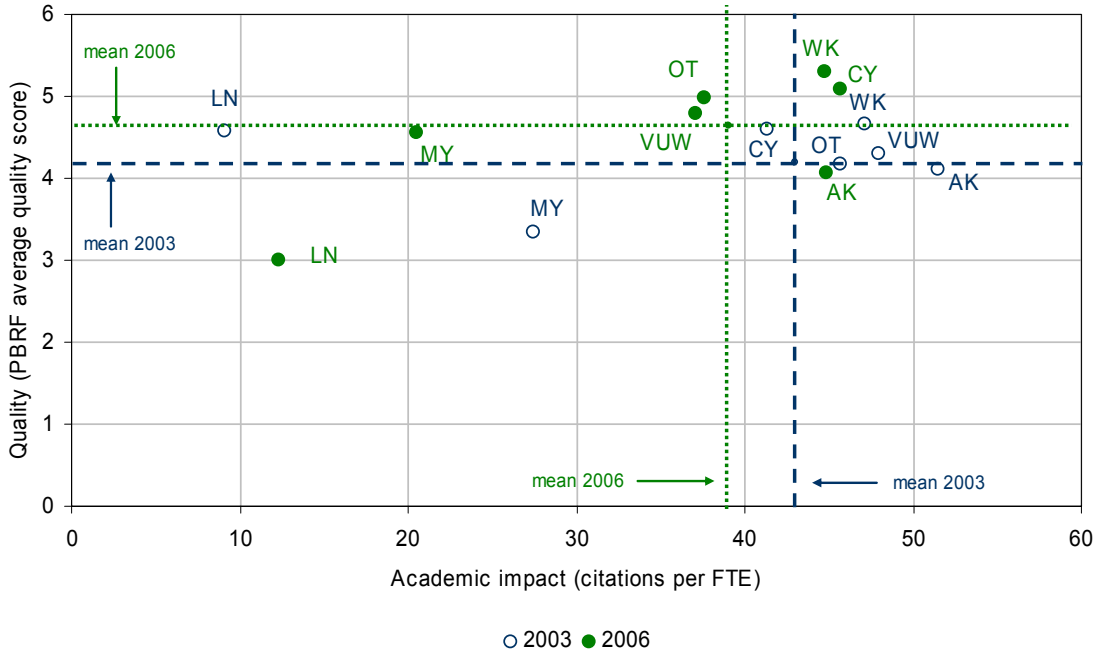
Figure 6 presents the academic impact and quality of research in 2003. Visually, it would appear that there is a relatively weak linear relationship between academic impact and research quality. Massey University and Lincoln University look to be outliers, while the remaining five universities in this panel are loosely grouped together around the mean value of academic impact and research quality. The Pearson's correlation coefficient is just 0.05 and the Spearman's rank order coefficient is negative and weak. Therefore, it would appear that the degree of association between academic impact and research quality is much stronger in 2006 than in 2003.

10 This may be an example of a situation where the research of some staff attracts many citations, but won't be reflected in a higher PBRF average quality score.

In tracking changes between periods, the mean academic impact decreased between 2003 and 2006, while the mean quality of research increased. Similarly, the direction of change in academic impact and research quality was the same at just two of the seven universities in this panel.

The University of Waikato is the only university that achieved above average research quality and academic impact in both 2003 and 2006.

Figure 6: Academic impact vs quality of research in 'physical sciences' by university 2003 and 2006



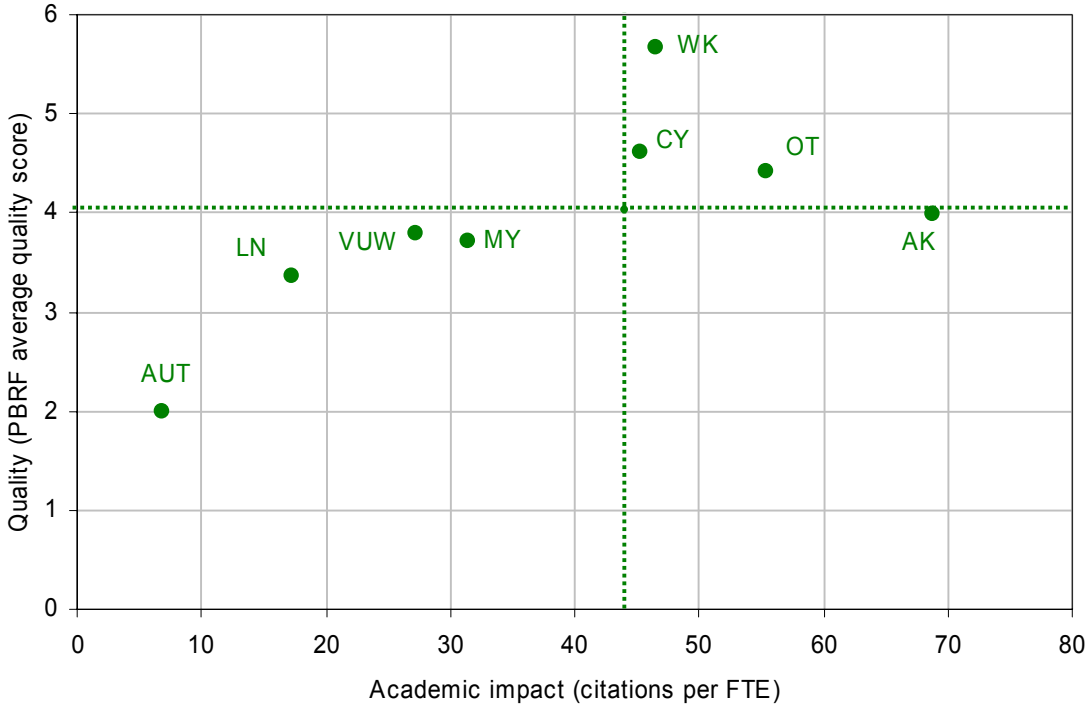
Notes:
1. The citations per FTE measure in 2003 is calculated by dividing the number of citations associated with publications listed in the Thomson Scientific dataset between 1998 and 2002 by the PBRF-eligible FTE in 2003.
2. The citations per FTE measure in 2006 is calculated by dividing the number of citations associated with publications listed in the Thomson Scientific dataset between 2001 and 2005 by the PBRF-eligible FTE in 2006.
3. The citations per FTE measure in 2003 has been adjusted for the effects of citation inflation.
4. The dotted lines in the graph illustrate the mean values.
Source: Thomson Scientific and the Tertiary Education Commission

4.5 Biological sciences

The academic impact and quality of research in the 'biological sciences' panel in 2006 is displayed in Figure 7. Visually, this subject panel shows a reasonable degree of positive linear correlation between the two measures, with the University of Auckland being a slight outlier. The Pearson's correlation coefficient value of 0.69 is reasonably high, although it is not statistically significant. The relationship between the rankings under the two measures is also reasonably strong, with the Spearman's rank order coefficient value of 0.76 being statistically significant. This degree of association is not unexpected, given that the Thomson Scientific dataset has good coverage in the biological sciences.

Three universities achieved above average academic impact and research quality in 2006 - the Universities of Canterbury, Otago and Waikato.

Figure 7: Academic impact vs quality of research in 'biological sciences' by university 2006



Notes:
1. The citations per FTE measure is calculated by dividing the number of citations associated with publications listed in the Thomson Scientific dataset between 2001 and 2005 by the PBRF-eligible FTE in 2006.
2. The dotted lines in the graph illustrate the mean values.
Source: Thomson Scientific and the Tertiary Education Commission

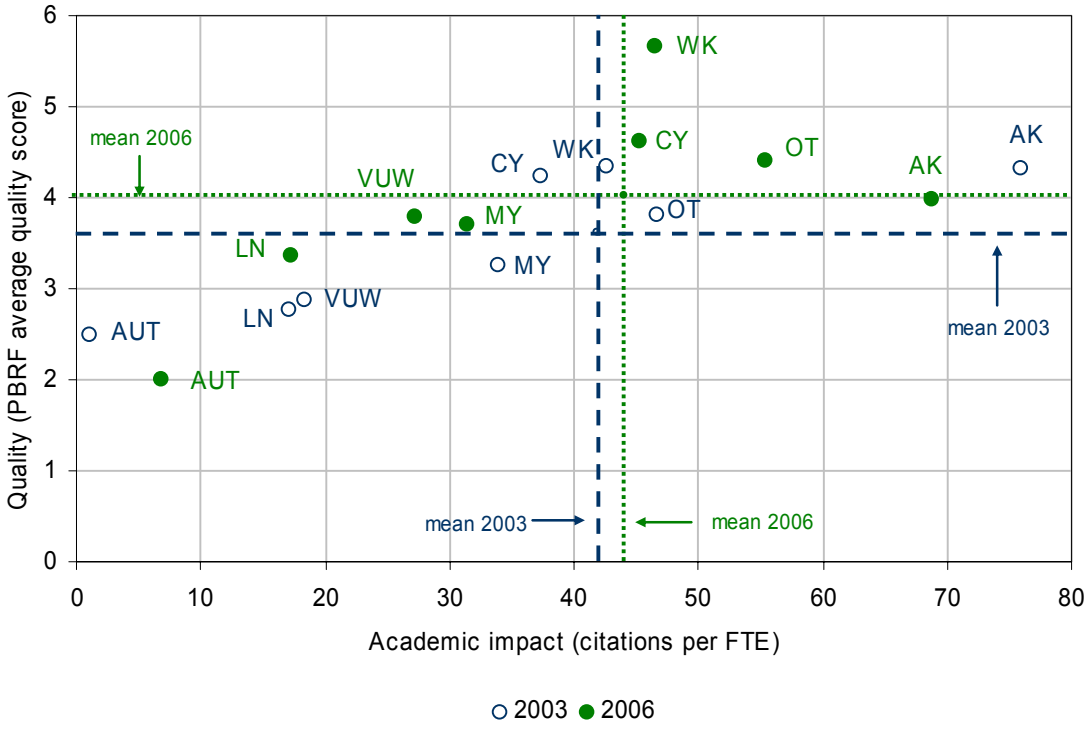
The relationship between academic impact and quality of research in 2003 is presented in Figure 8. It also shows a strong degree of linear correlation between the two measures which is arguably slightly better than in 2006. The numerical measures of association back this up - the Pearson's correlation coefficient value of 0.86 is among the highest of the 10 PBRF panels analysed in this report. Also, the Spearman's rank order coefficient of 0.91 is the highest of the 10 panels. Both measures are statistically significant.

Other evidence indicates the strength of the association between research quality and academic impact in this panel. For example, when combined, the 2003 and 2006 data shows a statistically significant Pearson's correlation coefficient and Spearman's rank order coefficient. In addition, an increase in the mean research quality is matched by an increase in mean academic impact between

2003 and 2006. Also, seven of the eight universities in this panel experienced movements in similar directions in academic impact and research quality between 2003 and 2006.

The Universities of Waikato and Otago are the only two universities to exhibit above average research quality and academic impact in both 2003 and 2006.

Figure 8: Academic impact vs quality of research in 'biological sciences' by university 2003 and 2006



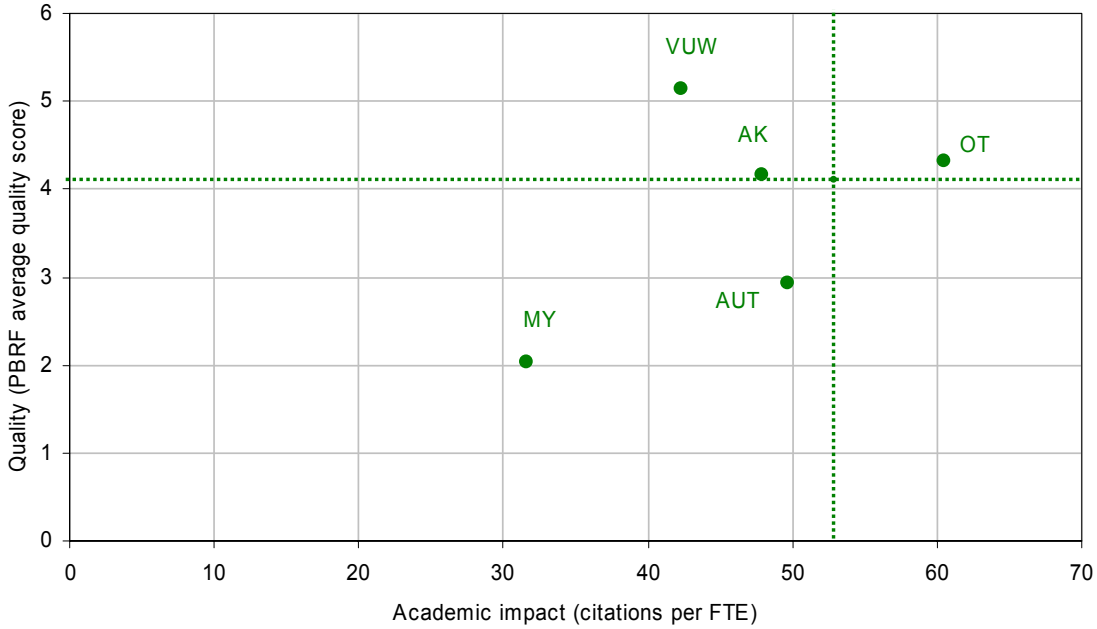
Notes:
1. The citations per FTE measure in 2003 is calculated by dividing the number of citations associated with publications listed in the Thomson Scientific dataset between 1998 and 2002 by the PBRF-eligible FTE in 2003.
2. The citations per FTE measure in 2006 is calculated by dividing the number of citations associated with publications listed in the Thomson Scientific dataset between 2001 and 2005 by the PBRF-eligible FTE in 2006.
3. The citations per FTE measure in 2003 has been adjusted for the effects of citation inflation.
4. The dotted lines in the graph illustrate the mean values.
Source: Thomson Scientific and the Tertiary Education Commission

4.6 Medicine and public health

Figure 9 presents the academic impact and quality of research in 2006 in the 'medicine and public health' panel. Given that there are only five observations in the 'medicine and public health' panel, it is difficult to assess the relationship between research quality and academic impact with any degree of confidence – especially when the two universities with medical schools, Auckland and Otago, dominate the quantity of research publications in this area. However, Figure 9 does not show a particularly strong linear correlation between academic impact and research quality. This is reinforced by the low Pearson's correlation coefficient of 0.49 which is not statistically significant. Similarly, the Spearman's rank order coefficient is also low (0.30) and not statistically significant.

Of the five universities in this panel, only the University of Otago exhibits research quality and academic impact above the university mean in 2006.

Figure 9: Academic impact vs quality of research in 'medicine and public health' by university 2006



Notes:
1. The citations per FTE measure is calculated by dividing the number of citations associated with publications listed in the Thomson Scientific dataset between 2001 and 2005 by the PBRF-eligible FTE in 2006.
2. The dotted lines in the graph illustrate the mean values.
Source: Thomson Scientific and the Tertiary Education Commission

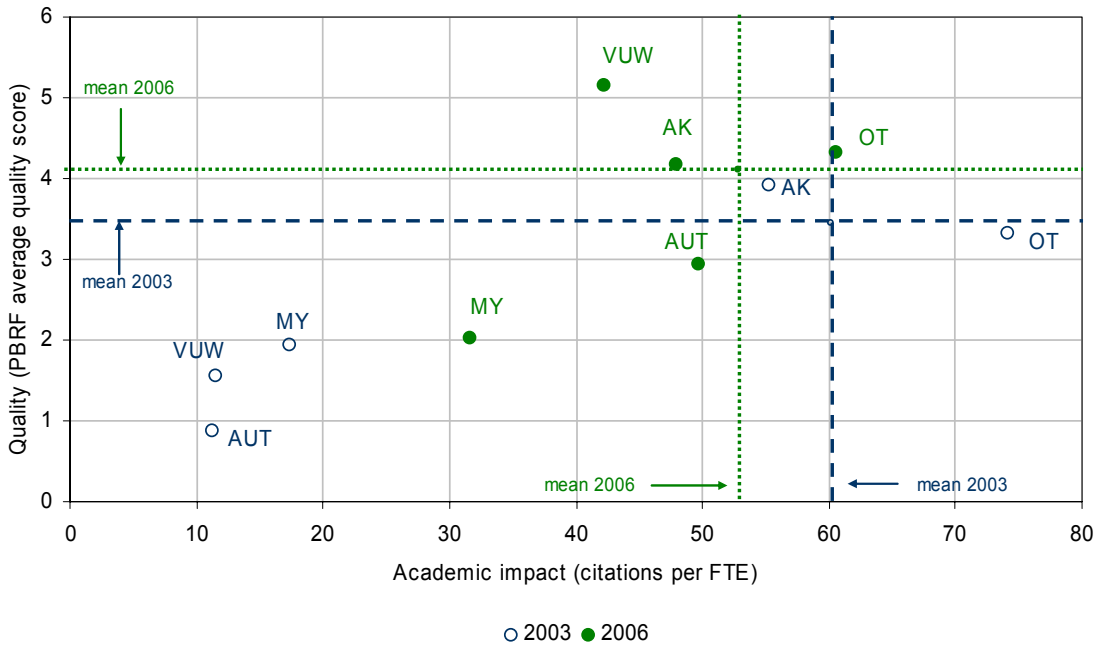
Figure 10 presents the research quality and academic impact of research in 2003. Visually, there appears to be a stronger degree of linear correlation between the two measures than in 2006. The statistics back this up - the Pearson's correlation coefficient of 0.89 is higher and statistically significant. Also, the Spearman's rank order coefficient value of 0.90 is much higher than in 2006 and is statistically significant. However, the lack of observations makes it difficult to be too definitive.

An examination of how the measures changed between 2003 and 2006 presents a mixed picture of how closely the measures are related. For example, while the mean research quality increased between 2003 and 2006, the mean academic impact of research fell. Also, at the two universities that have medical schools and therefore dominate this subject field, the Universities of Auckland an Otago, the increase in research quality recorded between 2003 and 2006 was not matched by an increase in

academic impact. However, the very significant increase in the quality of research by Victoria University of Wellington between 2003 and 2006 was matched by an equally significant rise in academic impact – offering an element of validation to the scale of this change.

No university achieved above average research quality and academic impact in both 2003 and 2006.

Figure 10: Academic impact vs quality of research in 'medicine and public health' by university 2003 and 2006



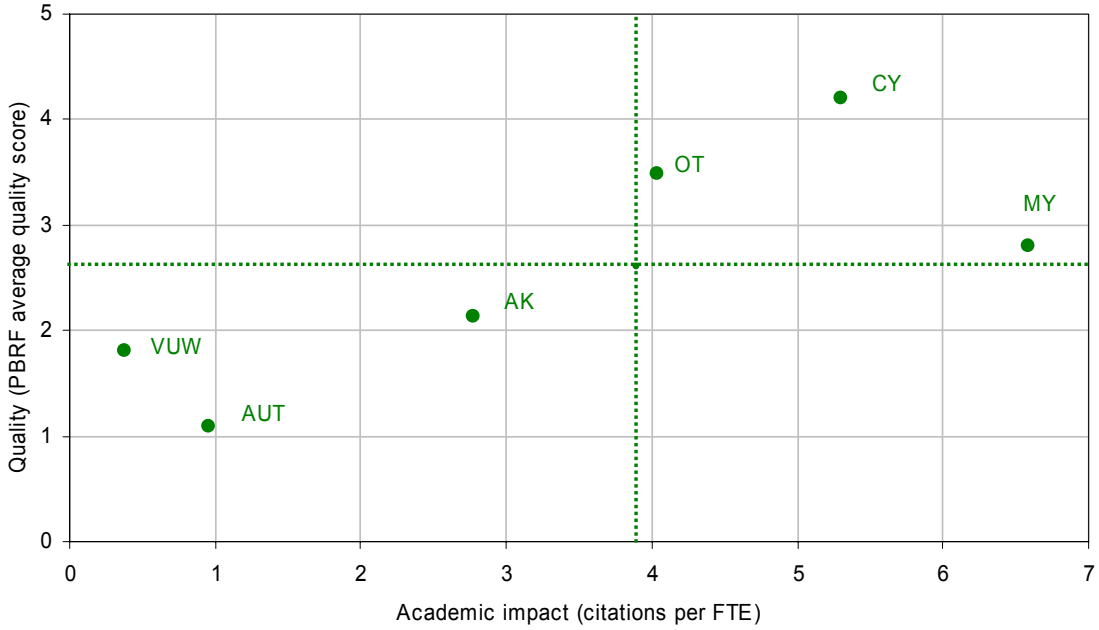
Notes:
1. The citations per FTE measure in 2003 is calculated by dividing the number of citations associated with publications listed in the Thomson Scientific dataset between 1998 and 2002 by the PBRF-eligible FTE in 2003.
2. The citations per FTE measure in 2006 is calculated by dividing the number of citations associated with publications listed in the Thomson Scientific dataset between 2001 and 2005 by the PBRF-eligible FTE in 2006.
3. The citations per FTE measure in 2003 has been adjusted for the effects of citation inflation.
4. The dotted lines in the graph illustrate the mean values.
Source: Thomson Scientific and the Tertiary Education Commission

4.7 Health

The association between research quality and academic impact in the 'health' panel in 2006 is displayed in Figure 11. As can be seen, there is some degree of positive linear correlation between the two measures, but there is also an outlier in the form of Massey University.[11] The Pearson's correlation coefficient value of 0.76 shows a reasonable association between the two variables, but is not statistically significant. Similarly, the relationship between the rankings of the universities under the two measures is not strong, given that the Spearman's rank order coefficient is not statistically significant.

The University of Otago, Massey University and the University of Canterbury all achieved higher than average research quality and academic impact in 2006.

Figure 11: Academic impact vs quality of research in 'health' by university 2006



Notes:
1. The citations per FTE measure is calculated by dividing the number of citations associated with publications listed in the Thomson Scientific dataset between 2001 and 2005 by the PBRF-eligible FTE in 2006.
2. The dotted lines in the graph illustrate the mean values.
Source: Thomson Scientific and the Tertiary Education Commission

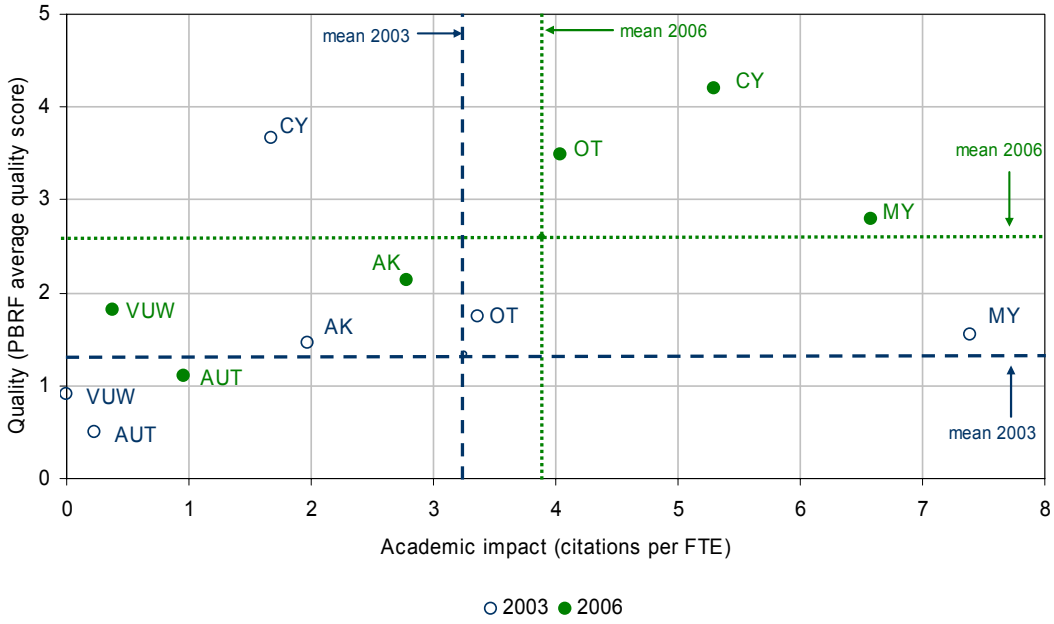
The relationship between academic impact and quality of research in the 'health' panel in 2003 is presented in Figure 12. As can be seen visually, the relationship between academic impact and research quality is significantly lower than was the case in 2006. In addition to Massey University, the University of Canterbury is also an outlier in 2003. The weaker association between research quality and academic impact in 2003 is reflected in the statistical measures of association - the Pearson's correlation coefficient is just 0.18 and is not statistically significant, and neither is the Spearman's rank order coefficient.

An examination of the changes in the two measures between 2003 and 2006 reveals a higher degree of association. The mean academic impact and mean research quality both increased between 2003 and 2006. Also, the direction of the change in academic impact and research quality was the same in five of the seven universities in this panel.

11 This is a result of a large number of citations in the narrow subject are of 'veterinary medicine/animal health', which boosts the academic impact in this broad subject area.

Massey University and the University of Otago exhibit research quality and academic impact above the university mean in both 2003 and 2006.

Figure 12: Academic impact vs quality of research in 'health' by university 2003 and 2006



Notes:
1. The citations per FTE measure in 2003 is calculated by dividing the number of citations associated with publications listed in the Thomson Scientific dataset between 1998 and 2002 by the PBRF-eligible FTE in 2003.
2. The citations per FTE measure in 2006 is calculated by dividing the number of citations associated with publications listed in the Thomson Scientific dataset between 2001 and 2005 by the PBRF-eligible FTE in 2006.
3. The citations per FTE measure in 2003 has been adjusted for the effects of citation inflation.
4. The dotted lines in the graph illustrate the mean values.
Source: Thomson Scientific and the Tertiary Education Commission

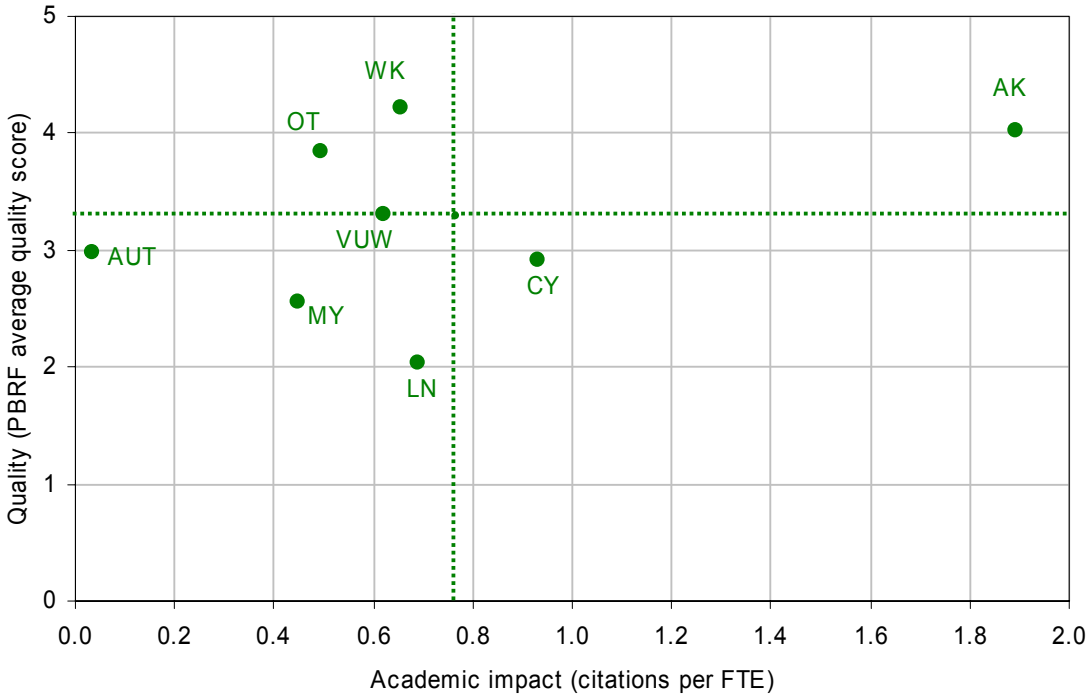
4.8 Business and economics

The academic impact and the quality of research in the 'business and economics' panel in 2006 is displayed in Figure 13. Visually, the degree of linear correlation between the two measures is very weak - the Pearson's correlation coefficient is just 0.35 and not statistically significant. The Spearman's rank coefficient value of 0.17 is also low and not statistically significant.

This low level of association between the two measures in this panel is not unexpected. A considerable proportion of research in this panel falls outside of the coverage of the Thomson Scientific dataset, which would lower the strength of the correlation between the measures.

The University of Auckland would appear to be somewhat of an outlier in Figure 13 and is the only university to achieve above average research quality and academic impact in 2006.

Figure 13: Academic impact vs quality of research in 'business and economics' by university 2006



Notes:
1. The citations per FTE measure is calculated by dividing the number of citations associated with publications listed in the Thomson Scientific dataset between 2001 and 2005 by the PBRF-eligible FTE in 2006.
2. The dotted lines in the graph illustrate the mean values.
Source: Thomson Scientific and the Tertiary Education Commission

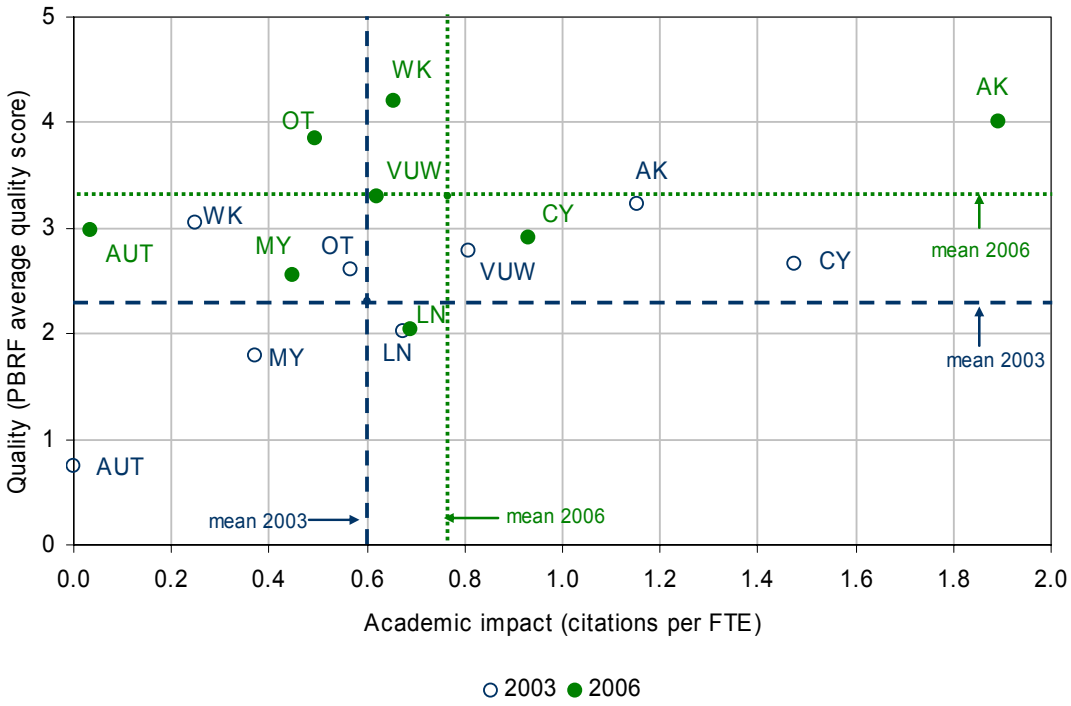
The relationship between academic impact and quality of research for the 'business and economics' panel in 2003 is presented in Figure 14. It would appear that there is a slightly better linear correlation between the two measures than in 2006, but the strength of that relationship still remains relatively weak. The Pearson's correlation coefficient is 0.63 in 2003, but is still not statistically significant. Similarly, the Spearman's rank coefficient of 0.52 is higher than in 2006, but is not statistically significant. Even when the data for the two years is combined, increasing the number of observations, the measures of association are still not statistically significant.

An examination of the change in academic impact and research quality between 2003 and 2006 shows that an increase in the mean value of academic impact was matched by an increase in

research quality. At the individual institution level, the direction of the change in research quality and academic was the same at five of the eight universities.

The University of Auckland is the only university that achieved above average research quality and academic impact in 2003 and 2006.

Figure 14: Academic impact vs quality of research in 'business and economics' by university 2003 and 2006



Notes:
1. The citations per FTE measure in 2003 is calculated by dividing the number of citations associated with publications listed in the Thomson Scientific dataset between 1998 and 2002 by the PBRF-eligible FTE in 2003.
2. The citations per FTE measure in 2006 is calculated by dividing the number of citations associated with publications listed in the Thomson Scientific dataset between 2001 and 2005 by the PBRF-eligible FTE in 2006.
3. The citations per FTE measure in 2003 has been adjusted for the effects of citation inflation.
4. The dotted lines in the graph illustrate the mean values.
Source: Thomson Scientific and the Tertiary Education Commission

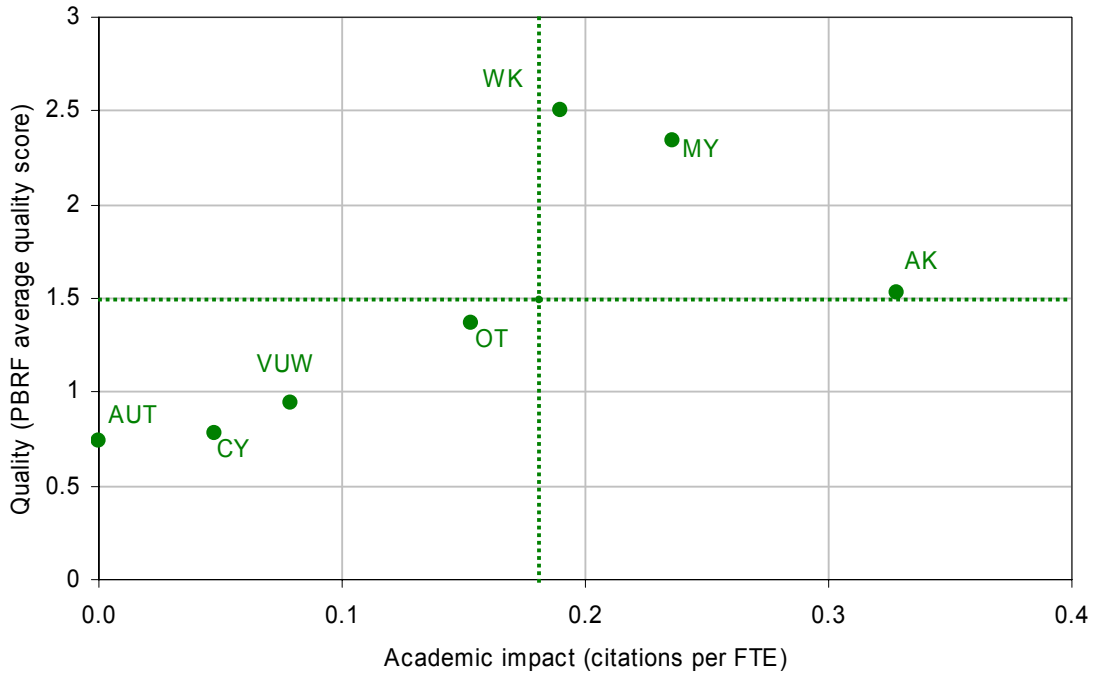
4.9 Education

The relationship between academic impact and quality of research in the 'education' panel in 2006 is presented in Figure 15. As can be seen, there is a reasonable degree of positive linear association between the two measures, with the University of Auckland being somewhat of an outlier. The University of Auckland achieved the highest academic impact value, but achieved a research quality score just above the university mean quality score. This is likely to be a result of one or two publications/authors being highly cited, and hence skewing the academic impact value upwards.

The Pearson's correlation coefficient is reasonable at 0.70, but is not statistically significant. The ranking of the universities in the two measures shows a strong relationship, with the Spearman's rank order coefficient value of 0.86 being statistically significant and one of the highest values recorded in this analysis.

There are three universities that achieved above average research quality and academic impact in 2006 – the Universities of Waikato and Auckland and Massey University.

Figure 15: Academic impact vs quality of research in 'education' by university 2006



Notes:
1. The citations per FTE measure is calculated by dividing the number of citations associated with publications listed in the Thomson Scientific dataset between 2001 and 2005 by the PBRF-eligible FTE in 2006.
2. The dotted lines in the graph illustrate the mean values.
Source: Thomson Scientific and the Tertiary Education Commission

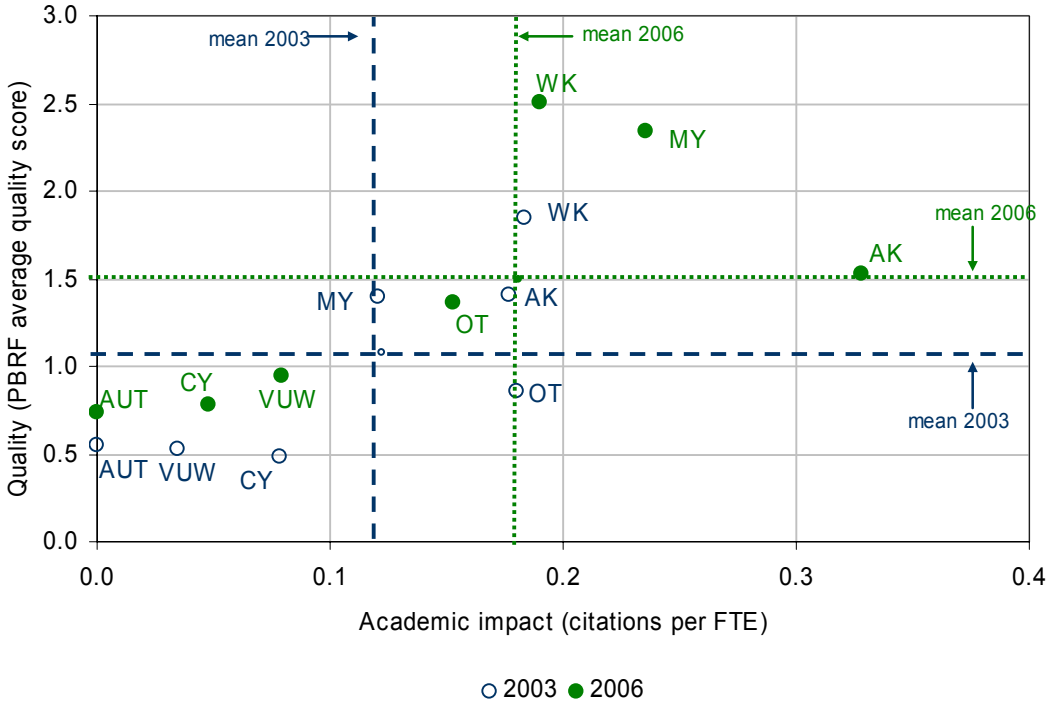
The relationship between academic impact and quality of research in 2003 is presented in Figure 16. Visually, there is a degree of positive linear correlation between the two measures. Although the Pearson's correlation coefficient value of 0.79 is slightly higher than in 2006 and is statistically significant, this does not necessarily reflect a better linear association between the two measures. The 2006 data is affected by the outlier. In 2003, there are no outliers, but there does appear to be a wider dispersion of the observations. The Spearman's rank coefficient of 0.82 is slightly lower than in 2006, but is still high and statistically significant.

When the 2003 and 2006 datasets are combined, both the Pearson's correlation coefficient and the Spearman's rank order coefficient are statistically significant and reasonably high in value. This strong degree of association is perhaps a little surprising, given the coverage of the Thomson Scientific dataset.

The mean academic impact and research quality both increased between 2003 and 2006. At the individual university level, four of the seven universities in this panel experienced changes in academic impact and research quality that were in the same direction.

The University of Auckland, Massey University and the University of Waikato all display academic impact and research quality above the university average in both 2003 and 2006.

Figure 16: Academic impact vs quality of research in 'education' by university 2003 and 2006



Notes:
1. The citations per FTE measure in 2003 is calculated by dividing the number of citations associated with publications listed in the Thomson Scientific dataset between 1998 and 2002 by the PBRF-eligible FTE in 2003.
2. The citations per FTE measure in 2006 is calculated by dividing the number of citations associated with publications listed in the Thomson Scientific dataset between 2001 and 2005 by the PBRF-eligible FTE in 2006.
3. The citations per FTE measure in 2003 has been adjusted for the effects of citation inflation.
4. The dotted lines in the graph illustrate the mean values.
Source: Thomson Scientific and the Tertiary Education Commission

4.10 Social sciences and other cultural/social studies

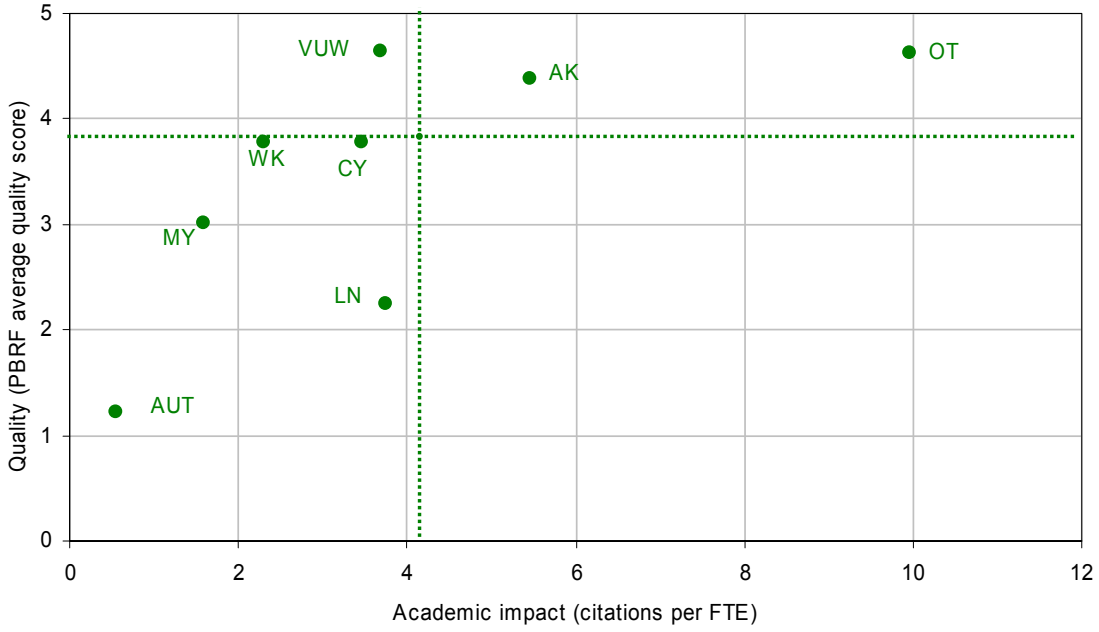
The relationship between academic impact and the quality of research in 2006 in the 'social sciences and other cultural/social studies' is presented in Figure 17. This shows that although there is an element of positive correlation between research quality and academic impact, that relationship is not particularly strong. There is an obvious outlier in the form of the University of Otago. This is partly a result of a higher number of citations associated with the narrow subject area of 'psychology'.

A reasonable degree of spread can be observed among the other seven universities. Certainly, they do not exhibit anywhere near a perfect linear relationship. This is reinforced by the Pearson's correlation coefficient value of 0.66 and the Spearman's rank order coefficient value of 0.64 – both of which are not statistically significant.

This relatively low level of association between academic impact and research quality in this panel is not unexpected, given the coverage of the Thomson Scientific dataset and the publishing conventions that apply in this subject area.

Two universities, Auckland and Otago, achieved higher than average academic impact and research quality in 2006.

Figure 17: Academic impact vs quality of research in 'social sciences and other cultural/social studies' by university 2006



Notes:
1. The citations per FTE measure is calculated by dividing the number of citations associated with publications listed in the Thomson Scientific dataset between 2001 and 2005 by the PBRF-eligible FTE in 2006.
2. The dotted lines in the graph illustrate the mean values.
Source: Thomson Scientific and the Tertiary Education Commission

The academic impact and quality of research in this panel in 2003 are presented in Figure 18. Generally the data in 2003 displays a similar pattern to that in 2006 – the University of Otago is a significant outlier and there is a reasonable spread in the measures of the remaining universities. The Pearson's correlation coefficient is lower in 2003 and is still not statistically significant. In terms of the relationship in the rankings of the universities in the two measures, there is a slightly stronger

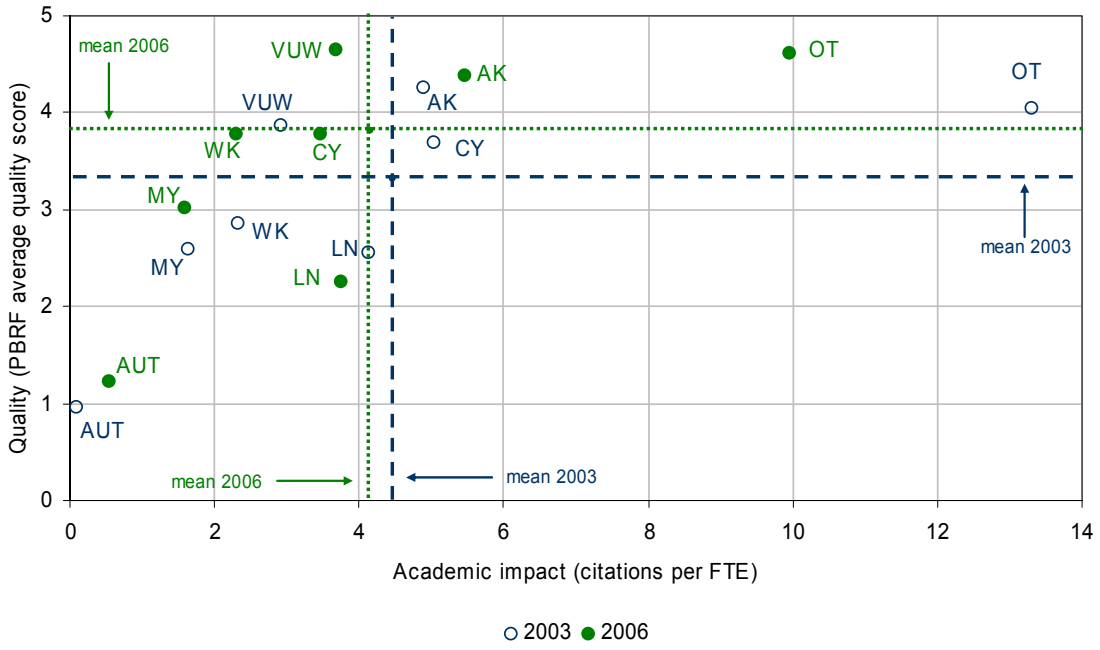
association in 2003, with a higher Spearman's rank order coefficient of 0.71 that is statistically significant.

When the 2003 and 2006 data is combined, the Pearson's correlation coefficient and Spearman's rank order coefficient are both statistically significant – a result partly due to the increase in the number of observations from combining the two datasets.

An examination of how the measures of academic impact and research quality changed between 2003 and 2006 shows that the means of these two measures moved in opposite directions – mean research quality increased while the mean academic impact decreased slightly. At the individual university level, just half of the eight universities in this panel experienced a change in academic impact and research quality that was in the same direction.

The Universities of Auckland and Otago achieved research quality and academic impact above the university mean in both 2003 and 2006.

Figure 18: Academic impact vs quality of research in 'social sciences and other cultural/social studies' by university 2003 and 2006



Notes:
1. The citations per FTE measure in 2003 is calculated by dividing the number of citations associated with publications listed in the Thomson Scientific dataset between 1998 and 2002 by the PBRF-eligible FTE in 2003.
2. The citations per FTE measure in 2006 is calculated by dividing the number of citations associated with publications listed in the Thomson Scientific dataset between 2001 and 2005 by the PBRF-eligible FTE in 2006.
3. The citations per FTE measure in 2003 has been adjusted for the effects of citation inflation.
4. The dotted lines in the graph illustrate the mean values.
Source: Thomson Scientific and the Tertiary Education Commission

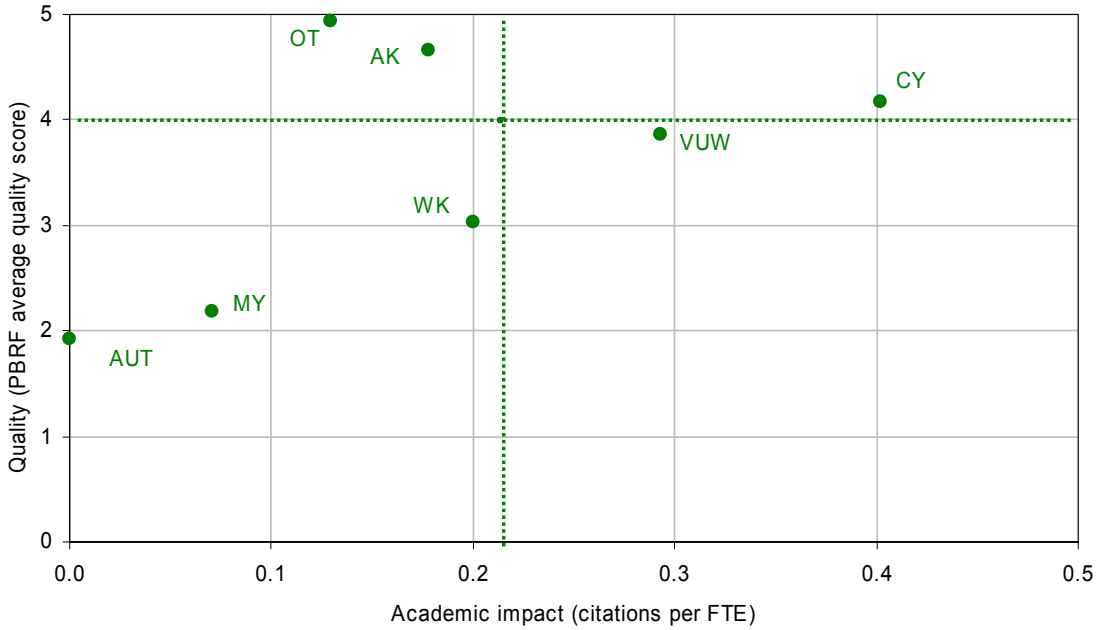
4.11 Humanities and law

The academic impact and quality of research in the 'humanities and law' panel in 2006 are presented in Figure 19. As can be seen, although there is an element of linear alignment between five of the eight universities, the Universities of Otago and Auckland are outliers. As a result, neither the Pearson's correlation coefficient value of 0.56 nor the Spearman's rank order coefficient value of 0.43 is statistically significant.

As was the case in the 'social science and other cultural/social studies' panel, a large amount of research in this area falls outside of the capture of the Thomson Scientific dataset. Therefore, this relatively low level of correlation is to be expected.

Only the University of Canterbury achieved above average academic impact and research quality in 2006.

Figure 19: Academic impact vs quality of research in 'humanities and law' by university 2006



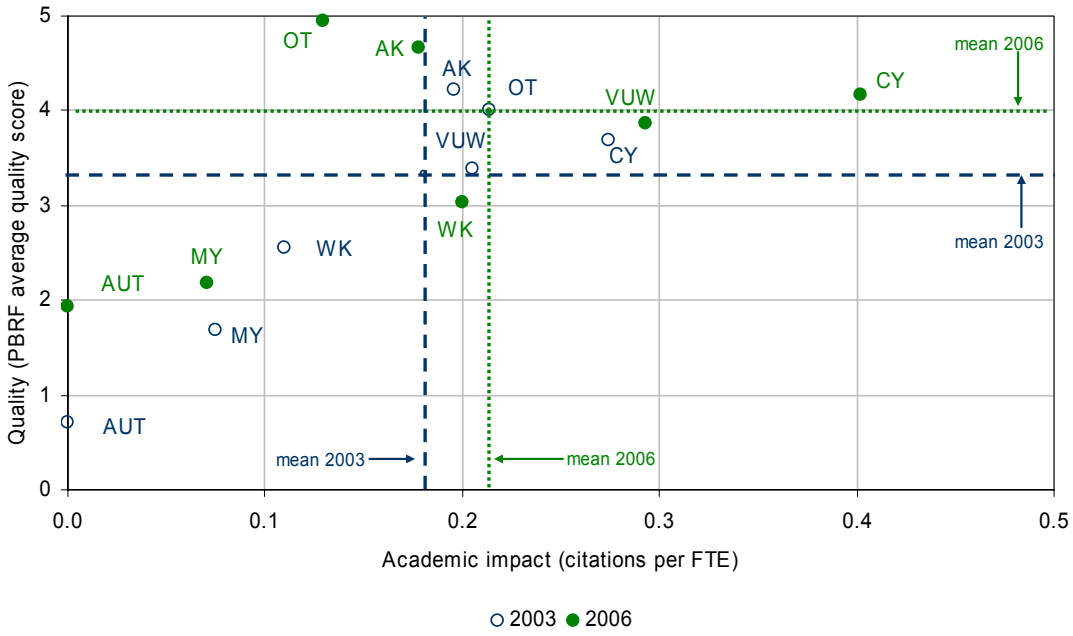
Notes:
1. The citations per FTE measure is calculated by dividing the number of citations associated with publications listed in the Thomson Scientific dataset between 2001 and 2005 by the PBRF-eligible FTE in 2006.
2. The dotted lines in the graph illustrate the mean values.
Source: Thomson Scientific and the Tertiary Education Commission

The academic impact and quality of research in this panel in 2003 are presented in Figure 20. It displays a somewhat higher degree of linear correlation than in 2006, with an especially high Pearson's correlation coefficient of 0.93 which is statistically significant. The Spearman's rank order coefficient value of 0.72 is higher than in 2006, but is not statistically significant. The strength of the linear correlation in this panel in 2003 is a little surprising, with the weaker 2006 result more in line with expectations.

An increase in the mean academic impact is mirrored by an increase in mean research quality between 2003 and 2006. However, the direction of change in academic impact and research quality was the same at just three of the seven universities.

The University of Canterbury is the only university to achieve above average research quality and academic impact in both 2003 and 2006.

Figure 20: Academic impact vs quality of research in 'humanities and law' by university 2003 and 2006



Notes:
1. The citations per FTE measure in 2003 is calculated by dividing the number of citations associated with publications listed in the Thomson Scientific dataset between 1998 and 2002 by the PBRF-eligible FTE in 2003.
2. The citations per FTE measure in 2006 is calculated by dividing the number of citations associated with publications listed in the Thomson Scientific dataset between 2001 and 2005 by the PBRF-eligible FTE in 2006.
3. The citations per FTE measure in 2003 has been adjusted for the effects of citation inflation.
4. The dotted lines in the graph illustrate the mean values.
Source: Thomson Scientific and the Tertiary Education Commission

5 Conclusion

The results in this report show that there is generally a positive association between the peer-assessed quality of research, as measured by the PBRF average quality scores, and academic impact, as measured by the number of citations per researcher. However, the strength of this relationship varies across subject areas. The 'biological sciences' display the highest degree of association between academic impact and research quality, while 'business and economics' display the weakest association. These results are in line with what one would expect, given the coverage of the Thomson Scientific dataset used in the analysis and the publishing conventions in the respective disciplines.

Generally, the strength of the correlation between research quality and academic impact is lower than was found in studies of narrow subject disciplines in the British Research Assessment Exercise - although the limitations of the citations dataset used in this analysis and the smaller number of observations available for New Zealand in each subject panel would be factors contributing to this result. However, the degree of variation between the research quality scores and academic impact suggests that the peer review process used in the PBRF Quality Evaluations is not simply mirroring what is shown in the citations data. In other words, peer assessment of research quality appears to be measuring something that citations alone do not. Therefore, this would suggest that the assessment of quality through peer assessment cannot simply be replaced by metrics such as citations.

Given the limitations of the data used in this analysis, further research, which links the citations directly to the researchers in the PBRF Quality Evaluation, would more conclusively indicate the strength of the association between research quality and academic impact.

Appendix A: Measures of association

Table 1: Measures of association between academic impact (citations per PBRF-eligible FTE staff) and quality (PBRF average quality score) of research by PBRF broad subject panel

	Pearson's correlation coefficient			Spearman's rank order coefficient		
PBRF panel	**2003**	**2006**	**2003 & 2006**	**2003**	**2006**	**2003 & 2006**
Engineering, technology and architecture	0.67	0.52	0.56*	0.48	0.86*	0.59*
Mathematical and information sciences and technology	0.70	0.51	0.57*	0.75*	0.74*	0.70*
Physical sciences	0.05	0.72	0.36	-0.22	0.57	0.04
Biological sciences	0.86*	0.69	0.74*	0.91*	0.76*	0.83*
Medicine and public health	0.89*	0.49	0.74*	0.90*	0.30	0.70*
Health	0.18	0.76	0.49	0.54	0.77	0.57*
Business and economics	0.63	0.35	0.45	0.52	0.17	0.31
Education	0.79*	0.70	0.74*	0.82*	0.86*	0.85*
Social sciences and other cultural/social studies	0.61	0.66	0.60*	0.71*	0.64	0.64*
Humanities and law	0.93*	0.56	0.70	0.72	0.43	0.62*

Note: * denotes significant at the five percent level.

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 & 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 & 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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MINISTRY OF EDUCATION

Te Tāhuhu o te Mātauranga