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Research Article

Research Diversification of Australian Universities and its Relationship with Citation-based Performance and Ranking

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ABSTRACT
This research aims to investigate whether universities should go for greater diversity in their research or specialise and concentrate their research and try to only excel in a few fields. To answer this question, we assess the association between universities' research diversification, measured by breadth and depth and their impact and ranking. Universities' diversification is measured based on the disciplinary ratings of universities in Excellence in Research for Australia (ERA 2018). Research output and citation impact data from In Cites database were used for the analysis. Breadth is measured by the ratio of the fields in which a university is active to the total number of fields. Depth is related to the ratings a university has received for its research fields. The results show a significant positive relationship between both university diversification indicators developed in this study and most of the university citation-based performance metrics and research ranking measures. In other words, universities which are active in more disciplines and are rated highly in ERA in terms of their research activity in those disciplines are more likely to have better citation impacts and rankings. Most universities appeared to be either in the high-breadth high-depth zone (including all Group of Eight universities) or in the low-breadth low-depth zone (mainly regional universities).

Keywords: Research diversification, Australia, Excellence in Research for Australia, University ranking, Citation impact, Research specialization.

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INTRODUCTION

Universities are routinely evaluated by governments for funding and other resource allocations using a range of international ranking systems to assess their performance. These rankings affect their international reputations and, consequently, the attention they receive from industry, other institutions and students around the world. National research evaluation schemes, such as Excellence in Research for Australia (ERA), have also been developed to evaluate universities. Therefore, universities are under pressure and in competition to perform better in different evaluations. University ranking, as Lopez-Illescas, de Moya-Anegon and Moed[1] argued, undergone considerable development since evaluations were first introduced. Research is the major aspect of universities' activities that is evaluated in all these ranking and evaluation systems. Research activities usually occur at disciplinary levels at universities, however, many rankings and evaluation systems' results are based on the aggregated performance of research activities. Reducing universities' research activities to a single dimension leads to poor judgment.[2]

Taking specialisation or concentration and diversification of research in universities into account is also very important for financial planning[3] and for cost efficiency analysis.[4,5] Therefore, as Abbott and Doucouliagos[6] suggested, specialisation is an important factor to consider. More recent studies such as[1] emphasised that university specialisation should be taken into account in the evaluation and rankings. Studies on the structure of universities such as[7] in Spain and Li *et al*.[8] in China also highlighted the need to look at disciplinary profiles. Therefore, when devising a strategy to enhance research impact, universities should take into account their activities at the disciplinary level and develop strategic directions accordingly.

Although there seems to be no doubt that disciplinary differences and specialisation should be incorporated for university ranking and other evaluation purposes, we do

not know enough about the effect of diversification or concentration of research on the performance of universities and their positions in evaluations or rankings. An old study[9] used the number of publications and citations to study how the size of national research in advanced countries is related to their degree of specialisation by fields of science. They found a negative correlation between the two variables. The results showed that countries such as the US, the UK, the Netherlands and Switzerland that are well-established in terms of science had a lower than expected degree of specialisation, which implied they had greater diversification. Pianta and Archibugi[9] considered specialisation as dispersion of publications and citations of a country in scientific fields. Over time, however, most countries reduced their scientific specialisation, despite the recent research on patents and technological specialisation.[9] Of course, we need to note that Pianta and Archibugi's study was at national level and the breadth of disciplines at country level is different from that at university level. Some studies such as Bourke and Butler[10] looked at diversification of research of academic departments but did not investigate its relationship with impact and performance.

Moed *et al*.[11] studied the relationships between university research performance and concentration of university research at an institutional level and at a national level. Their results showed that a larger publication output both at a national and an institutional level was associated with a higher performance measured by citation counts. They considered the number of publications as a measure of concentration. Their results indicated that concentration and performance were positively related in university research. Their study revealed a "tendency that the research in a particular subject field conducted in universities specializing in other fields outperforms the work in that field in institutions specializing in that field. This outcome may reflect that it is multi-disciplinary research that is the most promising and visible at the international research front and that this type of research tends to develop better in universities specializing in a particular domain and expanding their capabilities in that domain towards other fields" (p. 649). In another study,[12] researchers analysed data on input and output of some European universities and found that economies of scale (i.e. size of universities) and specialisation (i.e. covering many fields) both have a significant impact on the efficiency of the Humboldt model that includes a coexistence of teaching and research and coexistence of many disciplines within the same institution. Nevertheless, confirming previous findings, they found that specialisation did not have a significant impact on the efficiency of the research model. In a more recent study of EU countries,[13] Pastor and Serrano concluded that differences in the field of science specialisation might be one of the factors influencing considerable differences in output per capita (citable documents per R&D researcher) among the higher education institutions of EU countries.

Lopez-Illescas *et al*.[1] used a measure of disciplinary specialisation (called the Gini Index) for 50 Spanish Universities which showed the extent to which research papers are evenly distributed among disciplines in generalist universities. They also showed that research papers are more concentrated in particular disciplines in more specialised universities such as medical, agricultural or (poli-) technical focused universities. The outcome of their research was that categorisation of universities according to their disciplinary specialisation into three categories—generalist, moderately specialised and highly specialised—is useful and that disciplinary specialisation should be taken into account in university rankings. Another study of European universities in the field of medical sciences[14] concluded that size had a negative impact on research quality. Quality was higher in generalist universities and those with more international collaboration. Wolszczak-Derlacz[15] studied 500 European and American universities in terms of efficiency and found that older European universities were more efficient. Government funding and lower efficiency were correlated in Europe and universities in wealthier regions of Europe and the US were more efficient. A study by[16] at the national level of agricultural sciences showed that, if balanced with diversification, R&D could improve research performance.

Lee *et al*.[17] looked at research diversity, ubiquity and complexity of some top ranked universities around the world. They define revealed comparative advantage (RCA) for each discipline to measure 'level of specialisation' as the percentage of papers of a discipline in a university, divided by the percentage of all papers by that university over all papers in the dataset. They then define a variable to measure university diversity by adding the RCA values for all disciplines in a university. They investigated the relationship between RCA and university ranking (using Academic Ranking of World Universities (ARWU)), applying a first-order linear regression and found no statistical correlation. That could be due to the use of the top 50 universities of the world that have very similar characteristics in their analysis. Lee[18] applied the same method on Australian universities and again found no correlation between the diversity measure he developed and university ranking. However, Lee used Microsoft Academic to extract publications and noted that there are limitations with the affiliation data in that dataset. Lee also ignored name variations that might have been used in publications (e.g., University of Melbourne, The University of Melbourne, Melbourne University) and only focused on the official name and ignored the rest. This approach resulted in some publications for each institution being discarded, particularly for institutions with more than one variation of name.

While specialisation should be considered in the evaluations and rankings, an important question for universities might be whether they should go for greater diversity in their research or if they should specialise and concentrate their research and try to only excel in a few fields. There is a possibility that concentration or diversification influence performance. For instance, the economies of scope between disciplines might play a role as more disciplines might mean triggering knowledge exchange between disciplines and influence the performance. Therefore, this research aims to answer the following research question:

How does diversification of research relate to university citation-based performance and ranking?

ERA: Excellence in Research for Australia

Excellence in Research for Australia (ERA) is the Australian national research evaluation system that rates universities at a disciplinary level based on their research performance on a five-point scale (1 to 5). ERA is done every three years and takes into account both the quality and quantity of research. It measures quantity as the number of publications per academic staff and quality based on peer review (for social sciences, humanities and some other disciplines) or citation counts (for other disciplines where citation counts is a reliable measure). It also measures activity in terms of research income and application (patents, etc.). Overall, it has three dimensions including quality (citation counts and/or peer review), research activity (output, income, etc.) and research application (commercialization, patents etc.). ERA uses the Australian and New Zealand's Fields of Research (FoR) that is increasingly being used in scientometric studies[19] and by citation databases (e.g. Dimensions). The rating is not based on organizational units (i.e. departments or schools) but based on the assignment of research to FoR codes to research by researchers. Each article is assigned to one FoR code or a combination of FoR codes (with a total of 100% assignment for each article) by researchers themselves. For instance, a university might not have a Library and Information Science department or school but if there are researchers in that university whom their research falls in this area (0807 FoR code) and they can assign their research output and activity to this code to be assessed. FoR has 22 two-digit codes (main fields of research), which are divided into 157 four-digit codes (sub fields), which in turn are divided into 1,239 six-digit codes (disciplines). FoR has a hierarchical structure and rating might be done at the 2-digit level (e.g. 08: Information and Computing Sciences) or 4-digit level (e.g. 0807: Library and Information Studies). There is a volume threshold for rating in code. For instance, in 2018 if the number of outputs of a university in a specific code was below 50, it was not assessed in that code and therefore would be marked as 'Not assessed' in the results.

The following is an example of the FoR code hierarchy

08 INFORMATION AND COMPUTING SCIENCES

0801 Artificial Intelligence and Image Processing

080101 Adaptive Agents and Intelligent Robotics

…

0807 Library and Information Studies

080701 Aboriginal and Torres Strait Islander Knowledge Management

080702 Health Informatics

080703 Human Information Behaviour

….

The first ERA assessment was conducted and issued in 2010 when it replaced the old national evaluation system that was called the Research Quality Framework. Since then, four rounds of ERA have been conducted including 2010, 2012, 2015 and 2018. Although ERA was planned to happen every 3 years, the next round of ERA has been postponed and is planned for 2023.

METHODOLOGY

To answer the key research question of this study, we use citation impact indicators and data from the Australian national evaluation system (ERA) and InCites database. This study analyses the rating of 39 Australian universities in ERA. We calculate the following university research diversification measures using the ERA 2018 data:

- Diversification *Breadth*: the number of 4-digit FoR codes in which a university has been assessed and received a rating divided by the total number of 4-digit FoR codes (i.e. 157). This shows the ratio of fields in which the university is research active. In other words, it is interpreted as the breadth of research activity in a university or its diversification breadth. For instance, if a university has received a rating in 100 codes, its breadth would be 64% (i.e. 100/157).
- Diversification *Depth*: the sum of ratings a university has received for 4-digit FoR codes divided by the maximum possible value that the given university could receive, i.e. the number of 4-digit codes assessed multiplied by 5 (which is the highest rating). The higher the value the closer the university is to achieving the maximum depth or excellence in its research activity. This measure reflects the quality of diversification. For instance if a university

has received ratings in 100 codes and the sum of those ratings is 350, its depth would be 70% (i.e. 350/(100*5)).

- Average of ratings: Average of all the ratings a university has received for 4-digit codes.
- Variance of ratings: Variance of all the ratings a university has received for 4-digit codes which shows the disparity the ratings of the university's research in different fields.

To measure the performance of the university's research, we use some of the Incites' database (Clarivate Analytics) indicators as below. The indicators were obtained for 2016 which was the last year of the reference period for 2018 ERA. All definitions below, except for *h*-index, are from Clarivate Analytics.[20]

- Category Normalised Citation Impact: This is a modification of the category normalised citation impact taking into account the country/region where the institution is based.
- % Documents in Top 1%: Percentage of publications in the top 1% based on citations by category, year and document type.
- % Documents in Top 10%: Percentage of publications in the top 10% based on citations by category, year and document type.
- Impact Relative to World: Citation impact of the set of publications as a ratio of the world average.
- % Industry Collaborations: Percentage of publications that have co-authors from industry.
- % International Collaborations: Percentage of publications that have international co-authors.
- *h*-index: The maximum value of *h* such that the given author (in this case a university) has published *h* papers that have each been cited at least *h* times.[21]

Two international ranking are used to determine the universities' overall performance in the world: i) the CWTS Leiden Ranking (www.leidenranking.com); and ii) Round University Ranking (only its research indicators) (http://roundranking.com). These two ranking are chosen because they both use Web of Science data for research indicators, which matches with ERA 2018 use of Web of Science data for performance evaluation. The ranking of Australian universities for 2016 in these two ranking are considered.

For the purpose of comparison, we also use the following groupings of Australian universities:

- **Group of 8 (Go8) (https://go8.edu.au):** These are eight world-leading research intensive universities: the University of Adelaide, Australian National University, University of Melbourne, Monash University, University of New South Wales, University of Queensland, University of Sydney and University of Western Australia.
- **Regional Universities Network (RUN) (www.run.edu.au):** These are seven universities that are located also in regional Australia and have a commitment to regional development. They are Central Queensland University, Federation University Australia, Southern Cross University, University of New England, University of Southern Queensland, University of the Sunshine Coast and Charles Sturt University.
- **Innovative Research Universities (IRU) (www.iru.edu.au):** These are seven comprehensive universities committed to both teaching and research excellence, Charles Darwin University, James Cook University, Griffith University, La Trobe University, Flinders University, Murdoch University and Western Sydney University.

It should be noted that Australian universities, at least the ones included in this study, do not focus on single disciplines (e.g. technical universities or medical universities). Even universities such as RMIT and UTS that have the term technology in their name and might give the impression that it is a technology university, includes social sciences and other disciplines as well. Therefore, the comparison here is not between generalist universities and very specialised universities, rather the issue is the breadth of the disciplines a university covers. The other issue is that Australian universities, in comparison to those in European countries, are relatively new and therefore, the comparison is not between universities that are a few centuries old and universities that are new.

RESULTS

Table 1 shows the statistics for diversification breadth and depth of Australian Universities based on ERA 2018 data. Average of ratings of universities in different fields and variance of their ratings are also presented. The 3-letter abbreviations are the abbreviations used by the Australian Research Council. The colours in Tables 1 and 2 indicate groupings. Blue is Go8, orange is RUN and green is IRU. The rest of universities are in black. For instance, University of New South Wales (NSW) has a very high value of diversification depth (90.79) and a medium level of diversification breadth (56.69), while Charles Sturt University (CSU) has a medium level of diversification depth (51.25) and small amount of diversification breadth (24.20). The 'Average' column shows a university's overall performance as it is the mean of all its ratings in all fields. The highest average belongs to the Australian National University, ANU (4.62) and the lowest to Charles Sturt University (CSU) (2.55). The 'Variance' column shows how the ratings

Table 1: Statistics of diversification breadth and depth of universities in ERA 2018.

University	ERA Rank	Breadth %	Depth %	Average	Variance
Australian Catholic University (ACU)	34	11.46	83.33	4.17	0.85
Australian National University (ANU)	6	45.22	92.39	4.62	0.32
Bond University (BON)	38	5.73	60.00	3.00	1.00
Central Queensland University CQU)	35	12.10	68.42	3.42	1.59
Charles Darwin University (CDU)	37	7.01	76.36	3.82	1.16
Charles Sturt University (CSU)	28	24.20	51.05	2.55	1.12
Curtin University (CUT)	16	40.13	72.70	3.63	0.72
Deakin University (DKN)	18	33.12	85.00	4.25	0.62
Edith Cowan University (ECU)	32	15.92	65.60	3.28	1.46
Federation University Australia (FED)	36	9.55	72.00	3.60	1.83
Flinders University South Australia (FLN)	21	31.21	71.02	3.55	0.88
Griffith University (GRF)	12	38.85	79.34	3.97	0.77
James Cook University (JCU)	22	29.30	70.43	3.52	1.06
La Trobe University (LTU)	17	36.31	80.00	4.00	0.93
Macquarie University (MQU)	11	39.49	78.39	3.92	0.83
Monash University (MON)	4	59.24	87.74	4.39	0.44
Murdoch University (MUR)	25	27.39	65.12	3.26	1.05
Queensland University of Technology QUT)	9	38.22	82.67	4.13	0.59
Royal Melbourne Institute of Tech (RMT)	20	36.31	70.18	3.70	1.00
Southern Cross University (SCU)	31	12.74	83.00	4.15	1.40
Swinburne University of Technology (SWN)	23	25.48	79.50	3.98	0.69
University of Adelaide (ADE)	8	42.68	89.25	4.46	0.56
University of Canberra (CAN)	33	13.38	72.38	3.62	1.05
University of Melbourne (MEL)	1	68.15	88.41	4.42	0.66
University of New England (UNE)	26	19.75	78.71	3.94	1.26
University of New South Wales (NSW)	5	56.69	90.79	4.54	0.48
University of Newcastle (NEW)	15	38.22	79.67	3.98	1.34
University of Notre Dame Australia (NDA)	39	6.37	52.00	2.60	0.71
University of Queensland (QLD)	2	62.42	89.80	4.49	0.36
University of South Australia (USA)	24	24.84	80.00	4.00	0.84
University of Southern Queensland (USQ)	27	18.47	74.48	3.72	1.92
University of Sydney (SYD)	3	63.06	88.69	4.43	0.39
University of Tasmania (TAS)	12	39.49	78.06	3.90	0.84
University of Technology Sydney (UTS)	14	38.22	80.33	4.02	0.66
University of the Sunshine Coast (USC)	30	14.65	73.04	3.65	1.87
University of Western Australia (UWA)	7	45.86	83.61	4.18	0.60
University of Wollongong (WOL)	10	39.49	79.68	3.98	1.03
Victoria University (VIC)	29	17.20	65.19	3.26	1.20
Western Sydney University (WSU)	19	38.22	71.00	3.55	1.03

Table 2: Statistics of citation impact performance of universities.

University	WoS Docs	Cat. Norm. Citation Impact	% Docs in Top-1%	% Docs in Top-10%	*h*-Index	Impact Relative to World	% Industry Collab.	% Int. Collab.
ACU	1,077	1.5	3.9	16	36	1.5	0.3	45
ANU	5,033	1.8	2.9	18	73	2.3	1.3	54
BON	345	1.2	1.7	11	18	1.1	0.6	41
CQU	410	0.9	1.0	10	20	1.1	0.5	30
CDU	591	1.1	1.5	12	26	1.3	2.0	46
CSU	872	2	2.4	11	31	2.6	0.7	46
CUT	3,543	1.5	2.3	15	60	2.1	1.2	54
DKN	3,196	1.3	1.9	14	49	1.5	1.0	47
ECU	691	1.5	2.8	16	34	1.8	0.6	52
FED	412	1.3	1.2	12	18	0.9	0.2	36
FLN	2,258	1.4	1.5	12	45	1.8	1.4	42
GRF	3,188	1.6	2.4	14	56	1.9	0.9	45
JCU	1,756	1.8	2.9	16	51	2.3	1.1	52
LTU	2,107	1.6	2.3	14	46	1.8	0.9	36
MQU	2,850	1.4	2.3	15	50	1.7	1.8	49
MON	9,335	1.6	2.3	15	90	2.2	2.2	50
MUR	1,034	1.1	1.0	13	31	1.4	1.4	47
QUT	3,168	1.6	2.1	15	53	1.8	1.6	50
RMT	2,626	1.4	1.6	15	48	1.6	1.7	50
SCU	382	1.4	1.8	19	24	1.6	0	50
SWN	1,394	1.4	2.1	17	44	1.9	1.7	54
ADE	4,836	1.9	3.7	18	89	2.7	1.9	52
CAN	730	2	2.7	14	29	2.4	0.7	40
MEL	10,901	1.6	2.5	17	102	2.1	2.4	49
UNE	899	1.1	1.6	12	26	1.1	0.2	43
NSW	9,057	1.4	2.3	15	90	1.9	2.0	49
NEW	3,063	1.3	1.3	12	45	1.6	1.2	47
NDA	382	1	0.8	10	18	1	0.5	37
QLD	9,325	1.6	2.7	16	93	2.0	1.9	49
USA	2,218	1.5	2.3	14	45	1.9	1.4	47
USQ	504	1.3	1.2	12	24	1.2	0.8	49
SYD	11,805	1.7	2.6	16	102	2.1	2.6	49
TAS	2,414	1.4	2.1	14	46	1.8	1.2	46
UTS	2,802	1.5	2.8	18	52	1.6	1.9	56
USC	588	1.2	1.0	15	25	1.4	0	49
UWA	5,845	1.6	2.5	15	77	2.2	2.6	54
WOL	2,590	1.7	2.2	16	57	1.9	1.4	53
VIC	829	1.4	2.8	17	35	1.8	0.2	50
WSU	1,931	1.6	2.1	15	45	2.0	0.7	46

of the university in different fields are distributed. A larger variance value means higher disparity of a university's ratings. University of Southern Queensland (USQ) has the largest variance (1.92) while the lowest variance belongs to the ANU (0.32). This is because USQ was rated 5 in 15 fields, 3 in 5 fields and 2 in 9 fields and received no ratings of 4 or 1. On the other hand, ANU was rated 5 in 47 fields, 4 in 21 fields, 3 in 3 fields and it had no 2 or 1 ratings. Depth and breadth have a moderate correlation (r_s = .652, p <0.001).

Table 2 shows citation impact indicators for the universities. NSW, for instance, has published 9,057 articles in 2016 and its category normalised citation impact is 1.22 with 2.25% of its articles being among the top-1% and 14.94% of its articles being among the top- 10%, which are all good values. It has an *h*-index of 90 and 48.74% of its publications included international collaboration.

The scatter plot (Figure 1) shows the position of universities in terms of their diversification depth and breadth along with some research output (number of documents in 'Web of Science' shown by size of nodes) and 'impact relative to the world' for each university is illustrated using colour intensity. The shape of nodes represents different groupings. The lines in the middle show average of depth and breadth with 95% confidence interval (shaded area). The scatter plots show that group of eight (Go8) universities are in the top right quadrant as their depth and breadth are above the average and have the highest research output. Some universities, such as CSU, have below the average depth and breadth and are in the bottom left quadrant. Three universities (e.g. RMT) have above the average breadth but below the average depth (bottom right quadrant) and five universities (e.g. SWN) have above the average depth but below the average breadth (top left quadrant). Generally the average depth and breadth of universities during the last four rounds of ERA have been increasing as most universities have been increasing their depth and breadth. An animated scatter plot of depth and breadth of universities for ERA rankings for 2010, 2012, 2015 and 2018 is available at (http://tiny.cc/1ktobz).

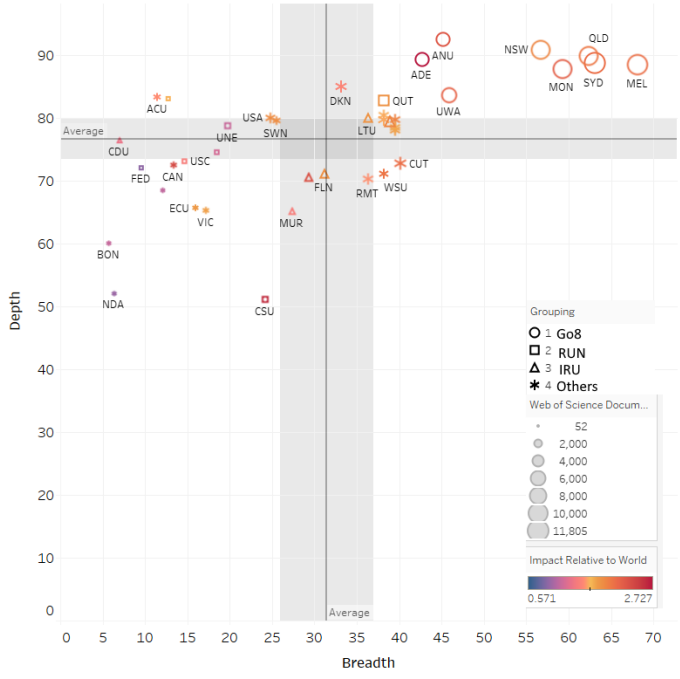

Figure 1: Scatter plot of diversification breadth and depth with output and impact.

While Go8 universities are closing the gap amongst them in terms of performance and are all moving to the upper right corner, universities in other coalitions i.e. regional network or innovative universities are not as homogenous in terms of their performance as the universities in Go8 are.

Spearman correlation values and scatter plots of two university rankings including Round research ranking and CWTS are presented in Figure 2. All of the correlation coefficient values were significant at 0.001 level. The negative values are because for ranking orders the lower the ranking value, the better. Diversification depth is strongly correlated with both rankings and universities that have higher depth perform better in that ranking. However, for Round research ranking, breadth seems to have a stronger correlation than depth. As expected, variance is correlated with the value of rankings. The lower the variance the better the rank of the university (i.e. the lower the rank order). This reflects higher ranked universities having more consistent (and most often higher value) ERA evaluation results across different fields of science.

Figure 3 shows the Spearman correlation and scatter plot of diversification values and research indicators. As expected, diversification breadth, depth and average show statistically significant positive correlations with all the impact variables with different strength levels. The strongest correlation of diversification *depth* is with *h*-index (0.702) and then with percentage of papers in top 10% (0.566). Its weakest

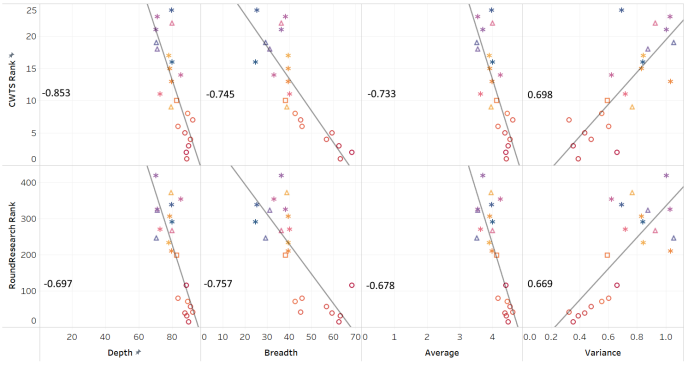

Figure 2: Scatter plot and correlation of diversification indicators with Round and CWTS ranking.
(all values are significant at p < 0.001).

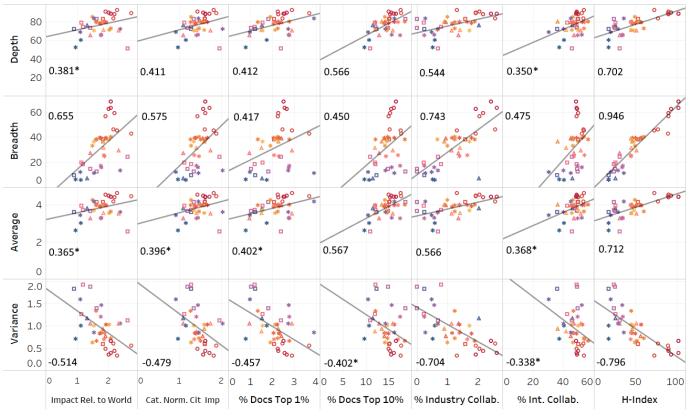

Figure 3: Scatter plot and correlation of diversification indicators and research performance indicators.
(*: sig <0.05, no asterisk: sig<0.01)

correlation is with percentage of papers with international collaboration. While the weakest correlation of diversification *breadth* is with the percentage of top 1% papers (0.417), its strongest correlations are h-index (0.946) and industry collaboration (0.743). The variance was negatively correlated with almost all of the impact indicators. This might be an indication that universities that have a mix of low and high-quality performance in ERA do not perform as well as those universities that rate consistently in whatever fields they are active in.

DISCUSSION AND CONCLUSION

This study used the rating of disciplinary research activities in Australian Universities' National Evaluation Systems called Excellence in Research for Australia (ERA) along with some citation impact indicators form Incites database to look at the relationship between diversification breadth and depth of research activity in universities and their citation impact performance. The results showed that diversification *depth*, measured by the ratings a university has received for its research fields, had moderate to strong correlations with some important citation impact indicators such as university *h*-index, impact relative to world and category normalised citation impact. It also had a statistically significant correlation with international collaboration. Universities diversification *breadth*, i.e. the ratio of active research fields to the total number of existing ERA fields (i.e. 22), was also correlated with their ranking in CWTS and Round University Rankings and their citation impact metrics.

However, diversification *breadth* was also correlated with diversification *depth*, indicating that universities which are active in a high number of research fields are also more likely to produce high-quality research. Being active in a wide range of research fields, which also means having more resources (human resources and/or equipment), facilitates interdisciplinary research not only internally but also externally and therefore, leads to higher quality research outputs. University of Melbourne (MEL) or Australian National University (ANU) are examples of such cases. Generally, it was clear in graphs that the Go8 universities all had high diversification breadth (active in many research fields) and high diversification depth (having higher ERA ratings) values. On the other hand, regional or teaching-focused universities such as Charles Sturt University (CSU), or Bond University (BON) were mostly in the bottom left quadrant of the breadth-depth graph with low diversification breadth and low depth values. These universities in the bottom left quadrant did not perform well in terms of citation impact or rankings. The other pattern evident from the data was that most of the universities were either in the high diversification breadth–high depth quadrant (top right) or in low diversification breadth–low depth quadrant (bottom left). Only a few universities were in the other two quadrants where they scored high in one and low in another of the two values of diversification breadth and depth. We should note that better performance is not necessarily a factor of the size of the university as previous research[22] showed that size is not a factor in the performance of universities while age might be a factor.

Individual indicators calculated in this study could also have implications for universities. For instance, the variance of FoR ratings for each university might have something to do with the recruitment policy of that university. A lower variance might mean that a university follows recruitment policies that set minimum standards across all areas. Ideally, the universities want to have higher FoR ratings in more fields and with lower variance of ratings.

The outcomes of this research can assist university boards and their strategic units to devise strategic decisions and plans when hiring new staff or investing funds in research activities to be active in more fields of science. Improving university ranking, which requires advancing research impact, is a long-term plan, with a long payback period, but promises to achieve a good return on investment (ROI) as it often leads to attracting more students and research funding. Advancing university rankings therefore affects the socio-economics of countries and reflects the countries' competitiveness.[23,18] Appropriate incentives and plans should also be developed at the national level.

This research had a few limitations as it relied on ERA data where an initial threshold applies to the ranking of fields for each university, however, the threshold is not large and if a university has 50 or more papers over a six-year period in a field, it will be assessed in that FoR code.

As a future work, other characteristics of the universities such as their size could be considered to develop normalised measures. Also, a more in-depth analysis of interdisciplinary activities will shed more light on the effects of interdisciplinary research on research performance. This may need the development of new metrics to measure university interdisciplinary activities.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

ABBREVIATIONS

CWTS: The Centre for Science and Technology Studies; **ERA:** Excellence in Research for Australia; **FoR:** Field of Research; **Go8:** Group of Eight.

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